4. Advanced Combustion Engines

Improving the efficiency of internal combustion engines is one of the most promising and cost-effective near- to mid-term approaches to increasing highway vehicles' fuel economy. The U.S. Department of Energy (DOE) Vehicle Technologies Office's (VTO) research and development activities address critical barriers to commercializing higher efficiency, very low emissions advanced internal combustion engines for passenger and commercial vehicles. This technology has great potential to reduce U.S. petroleum consumption, resulting in greater economic, environmental, and energy security.

Already offering outstanding drivability and reliability to over 230 million passenger vehicles, internal combustion engines have the potential to become substantially more efficient. Initial results from laboratory engine tests indicate that passenger vehicle fuel economy can be improved by more than 50%, and some vehicle simulation models estimate potential improvements of up to 75%. Advanced combustion engines can utilize renewable fuels, and when combined with hybrid electric powertrains could yield further reductions in fuel consumption. The U.S. Energy Information Administration (EIA) reference case forecasts that by 2040, more than 99% of light- and heavy-duty vehicles sold will still have internal combustion engines, therefore the potential fuel savings are tremendous.

VTO undertakes research and development activities to improve the efficiency of engines for both light and heavy-duty highway vehicles, whether they run on petroleum-based (gasoline and diesel) or alternative fuels. VTO supports every phase of research in these areas, from fundamental science to prototype demonstration. VTO's research focuses on improving engine efficiency while meeting future federal and state emissions regulations. It does this through three main approaches:

- Developing advanced combustion strategies that maximize energy efficiency while minimizing the formation of emissions within the engine.
- Developing cost-effective aftertreatment technologies that further reduce exhaust emissions at a minimum energy penalty.
- Reducing losses and recovering waste energy.

Commercialization of these advanced combustion engine technologies could allow the United States to cut its transportation fuel use and corresponding greenhouse gas emissions by as much as 20 to 40%.

The Advanced Combustion Engine R&D subprogram supports a number of unique user facilities at the national laboratories. In addition to the national laboratories, research and development is done in collaboration with industry, other federal agencies (such as the National Science Foundation) and universities, as well as through government/industry partnerships:

- The U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) Partnership focusing on light-duty vehicles; and
- The 21st Century Truck Partnership, focusing on heavy-duty vehicles.

The major goals of the Advanced Combustion Engines R&D subprogram are:

- By 2015, increase the efficiency of internal combustion engines for passenger vehicles resulting in fuel economy improvements of 25% for gasoline vehicles and 40% for diesel vehicles, compared to 2010 gasoline vehicles. By 2020, improve the fuel economy of gasoline vehicles by 35% and diesel vehicles by 50%, compared to 2010 gasoline vehicles.

- By 2015, increase the efficiency of internal combustion engines for commercial vehicles from 42% (2010 baseline) to 50 % (representing a 20% improvement). This goal is part of the overall SuperTruck initiative to increase Class 8 truck freight hauling efficiency by more than 50% by 2015. By 2020, further improve engine efficiency to 55% (representing a 30% improvement) with demonstrations on commercial vehicle platforms.

These research and development activities are described annually at the Merit Review, and Progress Reports.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2015 Annual Merit Review (AMR).

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1. Was the program area, including overall strategy, adequately covered?

Question 2. Is there an appropriate balance between near- mid- and long-term research and development?

Question 3. Were important issues and challenges identified?

Question 4. Are plans identified for addressing issues and challenges?

Question 5. Was progress clearly benchmarked against the previous year?

Question 6. Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7. Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8. What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9. Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10. Has the program area engaged appropriate partners?

Question 11. Is the program area collaborating with them effectively?

Question 12. Are there any gaps in the portfolio for this technology area?

Question 13. Are there topics that are not being adequately addressed?

Question 14. Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15. Can you recommend new ways to approach the barriers addressed by this program area?

Question 16. Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Subprogram Overview Comments: Gurpreet Singh (U.S. Department of Energy) – ace000

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:

The reviewer said that yes, the program was adequately covered, and elaborated that the overall program goals and strategy were clearly presented and tied back to end-use results.

Reviewer 2:

The reviewer remarked that the overall objective of removing barriers to mass commercialization of high efficiency vehicles was clearly communicated.

Reviewer 3:

The reviewer said that the presentation was very well thought out, outlining a strategy focusing on improving efficiency (and thus petroleum dependency) while reducing emissions. The reviewer noted that the role of government laboratories in fundamentals through applied research leading ultimately to technology transfer to industry was described well, followed up with a strong overview of the portfolio of projects being pursued by the laboratories and, in many cases, their industrial collaborators and partners.

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:

The reviewer noted that the bulk of the research & development (R&D) activity is mid-term to long-term. The reviewer identified that there are significantly fewer projects that are truly near-term, though that may be the most appropriate balance for this program area in any case, as near-term work is almost exclusively competitive in nature and therefore inappropriate for federal involvement.

Reviewer 2:

The reviewer said that there seems to be a balance of programs focused on near-, mid-, and long-term R&D.

Reviewer 3:

The reviewer noted that there is a clear pipeline of research bridging long-, mid-, and near-term work ranging from fundamental, laboratory research to near-production hardware proof-of-concept work. These various projects appear to be intelligently assigned to organizations best suited for their successful completion.

Question 3: Were important issues and challenges identified?

Reviewer 1:

The reviewer commented that the stage is set at the beginning of the presentation to give a good overview of the issues and challenges facing combustion engine development; targets and goals are clearly delineated.

Reviewer 2:

The reviewer noted that the issues of improving fuel consumption, reducing petroleum dependence, and continuing to reduce vehicle emissions were mentioned.

Reviewer 3:

The reviewer said that the important issues were well identified. The challenges were also largely covered in a useful way. The reviewer remarked that the main area where there may be disconnect is in coupling the technology R&D to consumer choice in purchasing the technology and the impact of fuel price. It is outside the scope of the Advanced Combustion Engine (ACE) program to fix those challenges, but they end up being a key factor in the speed of market penetration for the technology.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:

The reviewer said that a variety of approaches and programs were mentioned as the means for addressing the issues and challenges.

Reviewer 2:

The reviewer pointed out that although a high-level presentation, the overall program plan addresses the issues and challenges raised in reasonable detail given the time constraints of the venue. According to the reviewer, of course, this presentation naturally led into the more detailed individual project presentations to be covered during the subsequent sessions, but it was a good overview that laid out the general framework and a surprising amount of technical detail in so short a time.

Reviewer 3:

The reviewer remarked that these are reasonable plans. The reviewer expected that there will be many more challenges in implementing many of the technologies at the vehicle integration stage (transient performance, drive-cycle emissions, extreme environment compatibility, real-world fuel variability impact, etc.). The reviewer suggested that additional program focus on these topics at Oak Ridge National Laboratory (ORNL) and Argonne National Laboratory (ANL) would be valuable as these challenges can kill otherwise promising technologies and vehicle/engine manufacturers may or may not be willing to work on overcoming those challenges in their product development decisions.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:

The reviewer found that progress was well benchmarked in that the projects highlighted in the presentation demonstrated good advances from where the project team was in the previous year.

Reviewer 2:

The reviewer pointed out that recent progress was mentioned.

Reviewer 3:

The reviewer observed that progress is described more in multi-year terms rather than specifically geared towards the last year. In some ways, the reviewer found this is preferable as the problems being tackled are complex and take many years to reach final solution. However, the point is taken and perhaps some year-to-year benchmarks could be added.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:

The reviewer said that the projects in the ACE program are key parts of the broad problems/barriers that the VTO needs to address. The core importance of the internal combustion engine was well communicated in the presentation.

Reviewer 2:

The reviewer commented that the projects are focused on key issues of importance to VTO: improving fuel consumption, reducing petroleum dependence, and continuing to reduce vehicle emissions were all mentioned.

Reviewer 3:

The reviewer said that the projects here are very clearly working towards higher efficiency, energy independence, lower emissions, etc., which are all key problems and barriers that VTO is working to address.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:

The reviewer concluded that yes, the program area appears to be focused, well-managed and effective.

Reviewer 2:

The reviewer found that the program is well focused, covering most key areas needed to address the VTO's needs. It appears to be well-managed and effective, making significant progress on many fronts.

Reviewer 3:

The reviewer found that the program is highly focused and is well managed. The reviewer advised some broadening of the program, at least in a few key areas. The reviewer detailed that the program is heavily invested in low-temperature combustion and low-temperature catalysis. These two technologies are tied together, as engines using low-temperature combustion require the low-temperature catalysts. However, according to the reviewer, there are ongoing difficulties in fully integrating these engines into vehicles, such as acceptable transient performance, ability to boost and run sufficient exhaust gas recirculation (EGR), and catalyst thermal management for extended idle or hybrid applications. To provide some insurance against these integration-level challenges, the reviewer suggested that additional program activity looking at approaches that are less out-there but that also offer nearer-term potential would be of value. Some of these approaches might be high-dilution stoichiometric combustion where the aftertreatment is simpler, or advanced stratified compression ignition combustion that is not to the level of the premixed charge compression ignition/homogenous charge compression ignition/reactivity controlled compression ignition (RCCI).

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer identified that a key strength is a project portfolio in the advanced combustion area having a spectrum of different combustion approaches (i.e., dual fuel RCCI, partial premixing, lean and dilute EGR spark ignition, etc.) with a range from fundamental research to testing in multi-cylinder engines and vehicles.

Reviewer 2:

The reviewer remarked that the key strength is integrating the research between the laboratories, universities, and industrial partners. In most cases, the technologies being imagined and pursued at the fundamental level are filtering into the hands of the vehicle and engine manufacturers. The reviewer remarked that if anything, the collaborations between the laboratories, universities, and industry should be strengthened to speed-up this process. The reviewer said that where no clear commercialization path appears to be in place, for example the KIVA-hpFE development, more aggressive work towards getting the technology adopted by commercial software companies should be pursued.

Reviewer 3:

The reviewer identified that the work on stochastic processes is key; as the industry pushes the engines farther, the cycle-to-cycle variability becomes a huge limiting factor on getting efficiency. DOE's capability in this area is at the forefront of the subject. The reviewer noted that the Engine Collaboration Network (ECN) work is also a unique contribution that the DOE brings to the research community. The long-term work at Sandia National Laboratories in this area has been a massive investment in understanding compression ignition combustion. The reviewer remarked that the KIVA development is much weaker; DOE's own programs are splitting the effort between providing tools that plug into commercial codes like Converge, and still invest in the development of KIVA. But the reviewer sees significantly less interest in KIVA from the end users at engine/vehicle companies. It is not clear how this project provides value in proportion to its funding. The reviewer noted that the large awards to the engine/vehicle manufacturers are always somewhat challenging to rate. These projects demonstrate results, but provide minimal technical learning back to the combustion community, and there is not always an obvious linkage between the R&D and eventual product improvement. The reviewer does not know how to make this better, but it is something that stands out as a challenge.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:
The reviewer remarked that there is a good level of novelty and innovation in many of the projects. The projects variously leverage unique capability at the DOE laboratories, link together groups of researchers in ways that provide outsized benefits, and investigate topics that industry would not otherwise look to.

Reviewer 2:
The reviewer responded that yes, the ways to approach barriers are appropriate and elaborated that for the most part the national laboratory and university recipients of DOE awards are very knowledgeable and highly creative.

Reviewer 3:
The reviewer said that the projects show a lot of innovation being applied to overcoming the barriers.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer said that the program area has an excellent set of partners that cover key universities, the laboratory researchers, end-use industries (vehicle/engine manufacturers), and component suppliers.

Reviewer 2:
The reviewer identified that opportunities for engagement with industry range from annual AMR reviews, to semi-annual Advanced Engine Combustion Memorandum of Understanding (AEC MOU) meetings, to participation for some in specific programs. Some projects have significantly more engagement with industry than others.

Reviewer 3:
The reviewer commented that through the AEC MOU, many engine producers and energy companies have been engaged, while the DOE-National Science Foundation grants have brought in many leading universities into the mix. The reviewer noted that the Cross-Cut Lean Exhaust Emission Reduction Simulation (CLEERS) performs a similar role in the emissions control area. Greater participation by code vendors and component suppliers (injectors, turbos, etc.) might be helpful though.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer said that the collaborations appear to be effective with open communication in both directions.

Reviewer 2:
The reviewer said that there is clear and close collaboration between the various partners.

Reviewer 3:
The reviewer noted that for the overall program area, opportunities for engagement with the energy industry consists of the AMR and semi-annual AEC MOU meetings.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer saw no gaps.

Reviewer 2:
The reviewer referenced prior comments, and elaborated that additional projects looking at non-low-temperature combustion (LTC) areas would be the biggest gap this reviewer perceives, along with addressing challenges to implementing LTC on vehicles that can do everything that the vehicle has to do.

Reviewer 3:
The reviewer referenced prior comments that adding more participation by component and analysis tool providers might be beneficial.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer said that the portfolio appears to be very broad and addresses the problems adequately.

Reviewer 2:
The reviewer said none.

Reviewer 3:
The reviewer had no comments that would be different than prior comments.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
The reviewer said that funding appears adequate.

Reviewer 2:
The reviewer suggested seeing prior comments.

Reviewer 3:
The reviewer expressed no suggestions.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
The reviewer expressed a preference to see more of ORNL's and ANL's effort focused on going all the way to vehicles or at least simulated vehicle engine testing so that the full scope of making the combustion and catalyst developments coming out of the program are production-realizable.

Reviewer 2:
The reviewer suggested perhaps more focus groups like the ECN for other key issues, such as soot modeling for instance, may be helpful.

Reviewer 3:
The reviewer had no recommendations.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:
The reviewer said that additional discussion and information on technology needs would be valuable. The long-term plans are clearly heavily influenced by input from the automotive and truck manufacturers, but there sometimes appears to be disconnect between what these OEMs tell DOE to focus R&D on and what the manufacturers focus on for their visible R&D. This reviewer would like to see more obvious and visible

coordination and connection between DOE's projects and what ends up going towards production to ensure the best use of federal funds. The reviewer explained that there is huge potential in the internal combustion engine, so ensuring that what the ACE program works on gets to production will be a huge benefit to us all.

Reviewer 2:

The reviewer suggested perhaps sponsoring deep dive webinars for the various laboratory projects between AEC MOU meetings might provide some additional opportunities to interact with the researchers, and would result in getting more details out than possible in the twice annual meetings, etc.

Reviewer 3:

The reviewer stated no suggestions.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling	Musculus, Mark (SNL)	4-17	3.70	3.60	3.60	3.80	3.65
Light-Duty Diesel Combustion	Busch, Stephen (SNL)	4-22	3.20	3.00	3.30	3.30	3.13
Low-Temperature Gasoline Combustion (LTGC) Engine Research	Dec, John (SNL)	4-26	3.00	3.38	3.00	3.50	3.25
Spray Combustion Cross-Cut Engine Research	Pickett, Lyle (SNL)	4-28	3.67	3.67	3.75	3.42	3.65
Automotive Low-Temperature Gasoline Combustion Engine Research	Ekoto, Isaac (SNL)	4-33	2.70	3.00	3.60	2.90	2.99
Large Eddy Simulation (LES) Applied to Advanced Engine Combustion Research	Oefelein, Joe (SNL)	4-36	3.20	3.40	3.10	3.10	3.28
Fuel Injection and Spray Research Using X-Ray Diagnostics	Powell, Christopher (ANL)	4-41	3.38	3.38	3.13	3.00	3.30

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Use of Low-Cetane Fuel to Enable Low-Temperature Combustion	Ciatti, Steve (ANL)	4-45	3.29	3.00	3.14	3.29	3.13
Model Development and Analysis of Clean and Efficient Engine Combustion	Whitesides, Russell (LLNL)	4-50	3.50	3.33	3.42	3.00	3.34
Chemical Kinetic Models for Advanced Engine Combustion	Pitz, Bill (LLNL)	4-54	3.70	3.70	3.50	3.40	3.64
2015 KIVA-hpFE Development: A Robust and Accurate Engine Modeling Software	Carrington, David (LANL)	4-57	3.00	3.00	2.50	2.67	2.90
Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes	Daw, Stuart (ORNL)	4-62	3.00	3.10	2.80	3.10	3.04
High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Engines	Curran, Scott (ORNL)	4-67	3.50	3.25	3.33	3.25	3.32
Accelerating Predictive Simulation of Internal Combustion Engines with High Performance Computing	Edwards, Kevin (ORNL)	4-71	3.07	3.14	3.43	3.14	3.16

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Joint Development and Coordination of Emissions Control Data and Models (CLEERS Analysis and Coordination)	Daw, Stuart (ORNL)	4-77	3.88	3.75	3.75	3.38	3.73
CLEERS: Aftertreatment Modeling and Analysis	Peden, Chuck (PNNL)	4-81	3.25	3.50	4.00	3.25	3.47
Particulate Emissions Control by Advanced Filtration Systems for GDI Engines	Seong, Hee Je (ANL)	4-84	3.50	3.25	2.75	3.25	3.25
Enhanced High- and Low-Temperature Performance of NO_x Reduction Materials	Gao, Feng (PNNL)	4-86	3.67	3.33	3.33	3.33	3.42
Thermally Stable Ultra Low-Temperature Oxidation Catalysts	Karkamkar, Abhijeet (PNNL)	4-89	3.30	3.10	3.10	3.20	3.16
Cummins/ORNL-FEERC CRADA: NO_x Control and Measurement Technology for Heavy-Duty Diesel Engines	Partridge, Bill (ORNL)	4-93	3.40	3.40	3.60	3.30	3.41
Emissions Control for Lean Gasoline Engines	Parks, Jim (ORNL)	4-97	3.50	3.50	3.50	3.50	3.50

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Neutron Imaging of Advanced Transportation Technologies	Toops, Todd (ORNL)	4-101	3.30	3.30	3.40	3.00	3.28
RCM Studies to Enable Gasoline-Relevant Low-Temperature Combustion	Goldsborough, Scott (ANL)	4-105	3.50	3.13	3.38	3.13	3.25
Fuel-Neutral Studies of Particulate Matter Transport Emissions	Stewart, Mark (PNNL)	4-109	3.50	3.25	3.50	3.00	3.31
Cummins SuperTruck Program Technology and System Level Demonstration of Highly Efficient and Clean, Diesel Powered Class 8 Trucks	Koeberlein, David (Cummins)	4-112	3.71	3.79	3.79	3.67	3.75
SuperTruck Program: Engine Project Review	Singh, Sandeep (Detroit Diesel)	4-117	3.57	3.71	3.64	3.33	3.62
Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer	Zukouski, Russ (Navistar International Corp.)	4-122	3.08	2.92	3.42	2.92	3.02
Volvo SuperTruck - Powertrain Technologies for Efficiency Improvement	Gibble, John (Volvo)	4-126	3.56	3.44	3.50	3.31	3.46

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ATP-LD; Cummins Next-Generation Tier 2 Bin 2 Diesel Engine	Ruth, Michael (Cummins)	4-131	3.33	3.67	3.33	3.25	3.49
Advanced Gasoline Turbocharged Direct Injection (GTDI) Engine Development	Weaver, Corey (Ford Motor Company)	4-135	3.70	3.60	3.20	3.60	3.58
Advancements in Fuel Spray and Combustion Modeling with High Performance Computing Resources	Som, Sibendu (ANL)	4-139	3.30	3.40	3.60	3.20	3.38
Improved Solvers for Advanced Engine Combustion Simulation	McNenly, Matthew (LLNL)	4-143	3.50	3.70	3.50	3.80	3.64
Cummins/ORNL-FEERC Combustion CRADA: Characterization and Reduction of Combustion Variations	Partridge, Bill (ORNL)	4-147	3.50	2.90	3.30	3.00	3.11
Investigation of Mixed Oxide Catalysts for NO Oxidation	Szanyi, Janos (PNNL)	4-151	3.38	3.25	3.13	3.00	3.23
Robust Nitrogen Oxide/Ammonia Sensors for Vehicle On-board Emissions Control	Mukundan, Rangachary (LANL)	4-154	3.20	3.40	3.10	3.10	3.28

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
High Efficiency GDI Engine Research, with Emphasis on Ignition Systems	Wallner, Thomas (ANL)	4-157	2.92	3.25	2.92	3.08	3.10
Low-Temperature Emission Control to Enable Fuel Efficient Engine Commercialization	Toops, Todd (ORNL)	4-161	3.67	3.33	3.33	3.33	3.42
Next-Generation Ultra-Lean Burn Powertrain	Bunce, Mike (MAHLE Powertrain LLC)	4-164	3.14	3.07	2.79	3.17	3.07
Development of Radio Frequency Diesel Particulate Filter Sensor and Controls for Advanced Low-Pressure Drop Systems to Reduce Engine Fuel Consumption	Sappok, Alexander (Filter Sensing Technologies, Inc.)	4-169	3.50	3.70	3.50	3.30	3.58
High-Dilution Stoichiometric Gasoline Direct-Injection (SGDI) Combustion Control Development	Kaul, Brian (ORNL)	4-173	3.07	2.86	2.57	2.86	2.88
Intake Air Oxygen Sensor	Schnabel, Claus (Robert Bosch)	4-177	3.00	2.60	2.70	2.80	2.74
High-Efficiency VCR Engine with Variable Valve Actuation and New Supercharging Technology	Mendler, Charles (Envera LLC)	4-181	2.81	2.88	2.50	2.75	2.80

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Lean Miller Cycle System Development for Light-Duty Vehicles	Sczomak, David (General Motors)	4-186	3.42	3.08	2.50	3.50	3.15
Ultra-Efficient Light-Duty Powertrain with Gasoline Low-Temperature Combustion	Confer, Keith (Delphi Powertrain)	4-191	3.13	3.25	3.25	3.13	3.20
Metal Oxide Nano-Array Catalysts for Low-Temperature Diesel Oxidation	Gao, Pu-Xian (U. Conn)	4-195	3.50	3.30	3.20	3.30	3.34
Overall Average			**3.35**	**3.30**	**3.26**	**3.21**	**3.30**

Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling: Mark Musculus (Sandia National Laboratories) - ace001

Presenter

Mark Musculus, Sandia National Laboratories.

Reviewer Sample Size

A total of five reviewers evaluated this project.

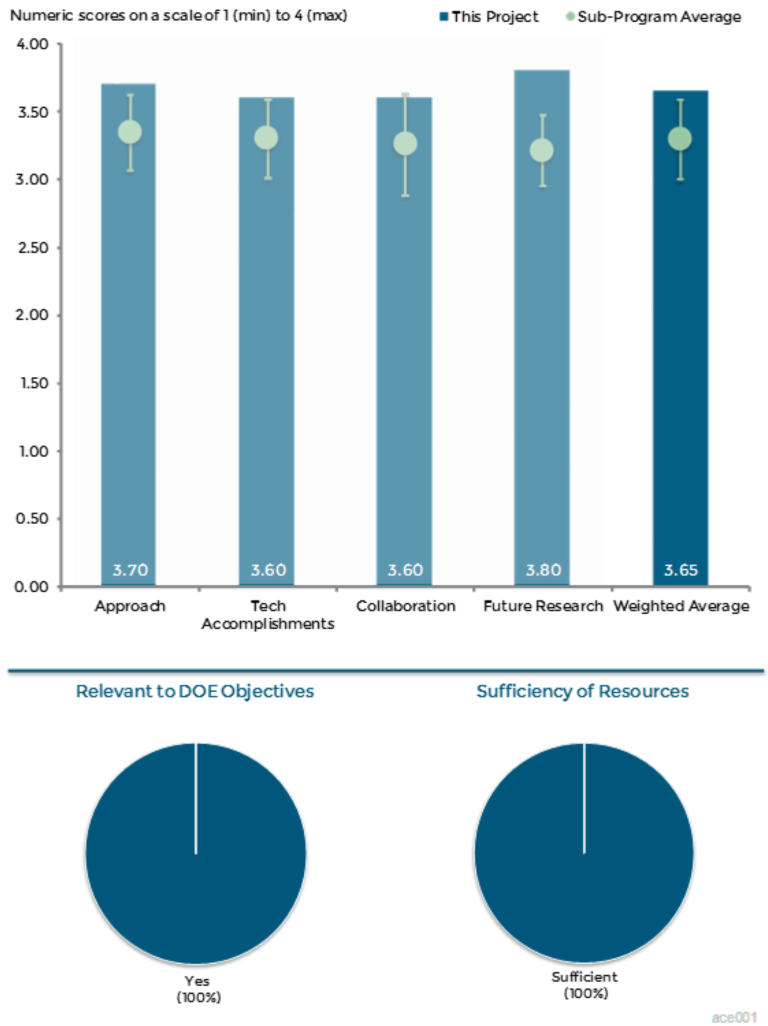

Figure 4-1 Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling: Mark Musculus (Sandia National Laboratories) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed the approach of combining planar laser-imaging diagnostics in optical engine with multi-dimensional computer modelling to better understand low-temperature combustion seems very effective.

Reviewer 2:

The reviewer acknowledged the project has a very thoughtful and stepwise approach to build the fundamental understanding of DI combustion, but warned that the biggest challenge is that so much is being done that it is hard to evaluate each piece fully with the limitations of the presentation time. The reviewer reported the top level goal is of great importance. The past findings at Sandia on diesel combustion have become an integral part of engine combustion knowledge and the extensions currently being worked on are equally important for future engine development. The reviewer remarked the development of the thermal imaging for vapor penetration is very interesting and would like to see more development and validation of the technique to understand it better. In addition, the heat transfer study is very important, though there will continue to be limitations since the work is on a skip-fired optical engine. The reviewer expressed an interest to see a specific collaboration with some other entity that could support metal engine experiments that extend/validate the work done. There is good justification made for some of the work to be done at Sandia National Laboratories (SNL) since correlation with the optical work is valuable. It was noted the soot formation and oxidation work is very exciting, and is a perfect example of the value of optical engine work since these results would be unobtainable anywhere else.

Reviewer 3:

The reviewer noted that the approach of using optical engine diagnostics with infrared imaging for study of vapor fuel mixing and combustion wall heat flux is very interesting and pointed out the infrared (IR) camera provides a simple setup to visualize vapor jet boundaries.

Reviewer 4:

The reviewer said that the combination of in-cylinder optical diagnostics and computational fluid dynamics (CFD) simulations are a powerful method to gain understanding of the various issues facing diesel engine designers, but warned that the broad scope of the research being pursued means that attention is being split many different ways. In addition, the comment was made that by focusing on fewer topics might provide greater leadership and progress in these areas.

Reviewer 5:

The reviewer suggested a recommendation for more emphasis on tool development to improve the science base of dilute spark ignition (SI) gasoline combustion.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer remarked that developing CFD analysis tools for insight into post injection mechanisms. The reviewer applauded the efforts with IR thermometry. The reviewer encouraged focusing on robust coating solution and eliminating pin holes.

Reviewer 2:

The reviewer remarked that there was clearly quite a bit of technical accomplishment. The biggest concern seen is that with four areas worked on, there would be concern that each got less time than it deserved for the value of each area individually. The reviewer observed that the partial premixing work is a project unto itself, and acknowledged that findings from this project with respect to mixing and incomplete combustion have been highly valuable over the years, and the complexity that comes with multiple injections makes this appear to be a massive undertaking. It was also pointed out that the results presented this year are a teaser for what will be done more than as results to work with independently. The reviewer commented that the vapor penetration diagnostic is a very interesting new tool, but expressed an interest to see much more on this task alone to find out what one has really learned from it and what else one could learn from it. It was mentioned the heat transfer work is another area where the tools are in development, but the results are not yet in. The reviewer also expressed an excitement to see what one learn in this area but there is not much to take away as a learning yet, and noticed the soot oxidation and formation work is very exciting and remarked to have some already useful learning from that work, even though it is going to be a continuing area of work.

Reviewer 3:

The reviewer observed that the discovery that in partial premixing, the increase in ignition delay with injection duration cannot be explained by mixture fraction, which is counter to what is expected. The reviewer mentioned that thermal IR imaging can provide vapor-fuel penetration data with simpler optical access requirements than Schlieren, and stated that there is some progress in evaluating two new heat transfer diagnostic methods which may ultimately help to improve accuracy of heat transfer models. Initial development of a soot formation and oxidation model that suggests as the post-injection fuel penetrates, it promotes faster combustion and consumes fuel from the main fuel injection and thus reduces soot from the main injection.

Reviewer 4:

The reviewer remarked that the progress is good in each area being investigated, but questioned if more significant progress could be made with more focused study of fewer topics.

Reviewer 5:

The reviewer observed that some very interesting conclusions were made with regard to the post injection interaction with the combustion residuals of main injection. It was pointed out that in future efforts from an industry perspective it would be great to expand on the idea of tailoring the mixing and scalar gradient distribution. The reviewer inquired about how that can be physically controlled with some injector or combustion bowl design changes. The reviewer commented that the observation of wall heat flux not being in phase with cylinder pressure can use some additional fundamental explanation.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer commented the collaboration with both direct partners and the Advanced Combustion and Emission Control (ACEC) team provides excellent coordination with relevant partners to address parts of the work which cannot be accommodated at SNL. In addition, the reviewer would encourage seeking some partnership that can support the heat flux measurements with metal engines and other measurement methods.

Reviewer 2:

The reviewer pointed out that the national laboratory interaction and collaboration in all of the Advanced Combustion Engine (ACE) projects are self-evident at Annual Merit Review (AMR). The community is excellently connected and efficiently shares research, and collaborates. The advanced engine combustion working group effectively disseminates information to the industry through workshops. The reviewer commented that it would be great to get a survey from the industry partners as to how this research gets translated into the workings of their own corporate research and development (R&D) departments.

Reviewer 3:

The reviewer offered that coordination with other U.S. Department of Energy (DOE) projects, particularly those at SNL, is very good. It was noted that more collaboration with other laboratories such as Argonne National Laboratory (ANL) with respect to their Advanced Photon Source (APS) injector studies would be welcomed. Similarly with universities, the reviewer said collaboration with the UW (UW), particularly in the area of CFD modeling, of effects of main/post injections and soot formation combined with in cylinder diagnostics at SNL is stunning, but can more be done by adding partners in other areas such as heat transfer which seems to be a topic of interest. The reviewer also remarked, for example, that there might be some work with Pennsylvania State University's radiation modeling National Science Foundation (NSF) project.

Reviewer 4:

The reviewer remarked that all work is conducted within Advanced Engine Combustion (AEC) which is a broad collaboration. It was said that other university contacts outside of AEC might better show leveraging of research findings.

Reviewer 5:

The reviewer pointed out that there is some collaboration with two original equipment manufacturers (OEMs) (Cummins & Delphi), one simulation software development company (Convergent Science, Inc. [CSI]), and one university, (UW). Collaboration with the AEC Memorandum of Understanding (MOU) members was generally mentioned, but no specifics were given. The reviewer stated that while collaboration may occur as part of these types of conference venues, very limited information was provided on planned collaborative efforts.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the future plans are exciting and follow the overall project strategy well. There is clearly a lot planned so making sure that there is adequate focus on each topic will be a challenge, as well as communicating the findings well.

Reviewer 2:

The reviewer remarked that the plans to continue building the conceptual model of multiple injection processes and determining how combustion design affects heat transfer and efficiency, should continue the very good progress that has been made.

Reviewer 3:

The reviewer observed heat transfer is a particularly interesting topic to diesel manufacturers trying to increase efficiency and maybe looking at thermal barrier coating and material effects might be worthwhile. However, the reviewer expressed a need to not add even more topics to an already crowded program. Soot diagnostics work and the relationships with injection should definitely be continued, but getting results in hands of modelers and ultimately commercial code vendors to aid in improving software tools should be a priority.

Reviewer 4:

The reviewer noted that the future work expands into more than two injection invents, and expressed that it would great to see some results in that scope next year. The reviewer remarked that some ideas are also required towards combustion control strategies.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer pointed out that improved understanding on spray, mixing, combustion may allow revised designs and strategies for improved fuel economy (FE) and lower emissions.

Reviewer 2:

The reviewer observed that a better understanding of the combustion process will lead to better engine designs with higher efficiencies and hence lower petroleum consumption.

Reviewer 3:

The reviewer expressed an agreement that the project and research is relevant to fundamental understanding of in-cylinder combustion processes towards enhancing efficiency.

Reviewer 4:

The reviewer pointed out that improving knowledge of in-cylinder spray, combustion, and pollutant formation processes for both conventional diesel and low-temperature combustion is important for the development and commercialization of more efficient engines that lead to lower petroleum usage.

Reviewer 5:

The reviewer highlighted that in terms of enabling high-efficiency direct injection (DI) combustion, the fundamental understanding that is being pursued is key for unlocking new concepts for production engines. The reviewer expressed a preference for a shift in balance towards more conventional combustion because aftertreatment effectiveness has improved enough to enable low NO_x and PM with a hot combustion system. Investigating if extensions to Dec's earlier work are warranted would be a useful parallel effort. This reviewer expressed a realization that runs counter to the comments on focus and multiple tasks from above and is not sure of how those could be reconciled.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer pointed out that approximately $834,000 per year is provided between SNL and UW, but mentioned that it is not clear what additional funding would directly allow.

Reviewer 2:
The reviewer indicated the resources appear to be adequate for allowing ongoing progress with good results on an annual basis. Having watched the program for many years, there is a significant track record of good progress at the funding levels which have been made available.

Reviewer 3:
The reviewer noted that good progress with existing funds suggests that funding is sufficient.

Reviewer 4:
The reviewer commented that the resources seem adequate.

Light-Duty Diesel Combustion: Stephen Busch (Sandia National Laboratories) - ace002

Presenter

Stephen Busch, Sandia National Laboratories.

Reviewer Sample Size

A total of five reviewers evaluated this project.

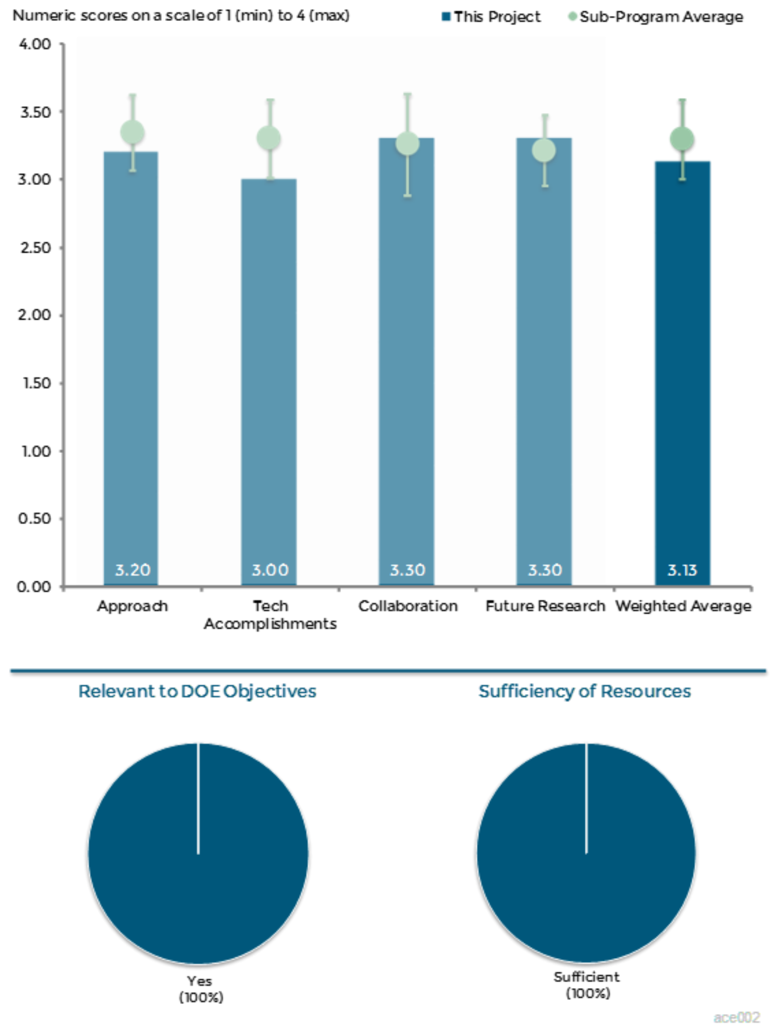

Figure 4-2 Light-Duty Diesel Combustion: Stephen Busch (Sandia National Laboratories) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that there is excellent close coupling between the experimental, diagnostics and simulation.

Reviewer 2:

The reviewer reported that the approach is good. It is made up of primarily optical engine work which is supported with simulations by UW and also has CFD support from CSI.

Reviewer 3:

The reviewer pointed out that this project appears to have received sustained activity for almost 20 years (since 1997). It is organized around developing a fundamental understanding of engine combustion processes through a combination of simulation and experiments, and the focus is on conventional combustion dynamics with emphasis this year on combustion noise. The test bed is a single cylinder engine at SNL where in-cylinder flow characterization is pursued and with UW using the data to develop improved predictions using the Converge code. The project notes that the General Motors (GM) 1.9 liter (L) engine is a common platform, though it seems that only the SNL optical engine (objective 1) and computational work (objective '). The reviewer questioned if a 1.9L engine was used, but acknowledged that the UW appears to be using the Converge code in their simulation to apparently improve its capabilities using the SNL single cylinder engine data. The reviewer noted that there are other parts of the Vehicle Technologies Office (VTO) program that are also using this same code, for example at ANL. It was questioned what UW is doing with Converge that ANL is not, or vice-versa. The reviewer noted that the use of KIVA has been extensively developed by UW in collaboration with SNL. UW and SNL are apparently now using Converge in this project. A comment was made that some discussion for the reason for the switch would be beneficial beyond simply that their industrial collaborators are using it. Presumably, the project team would be advocating for KIVA if it is felt it to be a valuable code.

Reviewer 4:

The reviewer warned that the presentation does not do a very good job of justifying the project relevance. Both this project and Musculus' project are looking at the impact of multiple injections. To be sure, there are differences between how the injection behaves in a large-bore and a small-bore engine, but there is little discussion of how the projects will be complementary in that regard. The reviewer commented that the project goals of evaluating combustion noise and engine efficiency are at odds with the experimental hardware. Those topics would be much more effectively studied on multi-cylinder engines (MCE) with real hardware. It was pointed out there is not much value to optical tools for either of those areas. If the reviewer missed something, it should have been brought out in the slides. The reviewer noted that there is also little discussion of how light-duty compression ignition (CI) engines are developing in the production/pre-production world. The challenges of simply meeting Tier 3/Low Emission Vehicle (LEV) III emissions is a huge challenge for light-duty CI engines going forward. The reviewer commented that support from SNL on technical issues still would support the DOE objective of petroleum reduction. This reviewer noted that if emissions regulations push diesel engines out of the light-duty market then fuel consumption will increase. The reviewer mentioned that more background needs to come across in terms of how the present work improves or replaces work done previously on the program by Miles, and commented that just showing the particle image velocimetry (PIV) results superficially looks like a repeat of work that has been done, which makes it hard for the reviewers to fairly evaluate the current efforts.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that understanding of noise reduction mechanism thru multiple injections will be very interesting and much needed, but was not sure how heat release from the pilot (1.5 milligrams (mg) can cancel that from main (20 mg). The reviewer commented that the efforts to validate models are encouraged and commended, and observed that an effort to correct PIV distortion is commendable. It is encouraging to see that swirl ratio from PIV correlates with swirl ratio form steady state bench. This reviewer remarked that the CSI simulations also predict the same swirl center location. Axis tilt with crank angle is qualitative early, but much better later on. The reviewer understands that the PI is having problems measuring squish flows and that these problems with PIV are associated with trying to get a thin laser sheet in the squish region, and mentioned that the beam steering and reflections occur. It was questioned if the project team can do Laser Doppler Anemometry (LDA) measurements. The reviewer mentioned that about 30 years ago, LDA was used to measure squish flows, and questioned if simulations have been exercised to see what the PI can expect for squish flow behavior.

Reviewer 2:

The reviewer said that leveraging destructive interference is an interesting approach, but questioned if there is concern this would not be robust in a production type environment. The reviewer asked if there is any consideration of an adaptive approach using sensor feedback, but commented that it was good to see combustion noise metric decibel (dBA) rather than ringing intensity.

Reviewer 3:

The reviewer stated that the main accomplishment seen in the presentation is that better PIV results are available which can be used to validate CFD, which is useful, and is a necessary step towards higher fidelity simulations. It was reported that it is not presented in a context where one can point to specific improvements in our understanding of light-duty CI combustion. This reviewer then pointed out that, in general, that is the biggest strength of the SNL is optical work, and the improvement in CFD models is a nice second outcome. The combustion noise result seems interesting, but it is very unclear if this finding is particularly useful. Beyond that, the study does not seem to make use of any specific capability that the optical engine offers. If it does not, then the study should probably be done elsewhere so that resources at SNL can be devoted to what only can be done there.

Reviewer 4:

The reviewer described the time for analytical image processing for distortion correction as well spent.

Reviewer 5:

The reviewer indicated that the connection between an improved understanding of flow in the SNL engine and measureable and quantifiable gains in engine efficiency were weak, and explained that detailed PIV measurements and turbulent flow in-cylinder simulations are interesting and can provide much needed data for validating engine codes. However, a greater connection of the results to engine efficiency would be beneficial. The reviewer highlighted that the science is good, but the connection to efficiency needs to be strengthened.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer stated that there is good coordination with UW and CSI, which will enable advances in modeling tools. There needs to be much stronger coordination with the engine manufacturers and probably with Oak Ridge National Laboratory (ORNL), as planned, but there are a number of aspects to this program that seem better suited to metal engine experiments or to close linkage to parallel metal engine experiments.

Reviewer 2:

The reviewer commented that the project team has very good collaborations exist with UW and CSI.

Reviewer 3:

The reviewer indicated that the collaborative team makes sense, including team members who are experts with experiments and computational simulations. It was pointed out there are other organizations that are developing numerical tools using similar data (e.g., single cylinder engine data) that have ostensibly similar computational capabilities. The reviewer suggested that it would be useful to reach out (if only informally) to such groups to see where there may be overlap.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer reported that the squish flow work is valuable and indicated much of the emissions and heat transfer can be tied to flow and combustion in this area. The reviewer then stated that the split injection work needs to be differentiated from the work on the heavy-duty CI engine somehow. It was explained there are obvious differences in the combustion system but it is not clear from the material presented how the proposed work will fit with the other project. The reviewer also suggested that better differentiation between the work at UW and CSI is probably needed as well to make clear where the advanced research on CFD and the production enabling of CFD come into play.

Reviewer 2:

The reviewer remarked that the code selected for study (Converge) provides impressive simulations as noted in the presentation. However, this reviewer mentioned that the PIs have also developed impressive simulations with other codes in their past work (KIVA). It was reviewer this issue deserves some further attention in their work going forward. The reviewer said the plan to study piston bowl geometries is interesting, though some work along this line has been reported in the past, but commented that it was not clear what is new here, or what rationale is being applied to inform the selection of the bowl geometry. This reviewer then concluded that it seemed sort of like a trial process to fabricate a bowl geometry, see how it performs and then revise it. The reviewer pointed out that the future work seems to be framed around the SNL single cylinder engine, but noted it is unclear how the GM 1.9L engine fits into the work going forward. The reviewer indicated that the computational work seems to focus on single cylinder performance predictions with the Converge growth, but warned it was not clear from what was presented if the computational tools have the capability to couple fluid/thermal transport processes and materials stress issues that result from repeated temperature cycling as the engine operates. If not, and the presentation did not appear to mention this issue, this should be included in future work. It was explained that materials issues can be determinative to long term performance at high engine efficiency. Issues like yield stress, crack growth and failure, etc., are important considerations in long-term sustained operation, especially because these properties are strongly coupled to temperature which is an output of the computational effort of the in-cylinder predictions. The reviewer concluded that the computational work should endeavor to integrate such coupling to make the computational tools more relevant to long-term engine performance.

Reviewer 3:

The reviewer indicated that squish flow behavior should be understood early by exercising the model, and this will help understand to interpret engine data when injection timings are swept.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer commented that this work is broadly relevant to engine performance as it concerns predicting in-cylinder processes and noise generated by the combustion process, but added that to make the work even more relevant, the PIs should try to quantitatively couple what the team is doing to specific efficiency metrics, and to fold materials stress considerations into their predictions.

Reviewer 2:

The reviewer expressed that there are needs to improve fuel economy from light duty (LD) diesel engines and at a high level the project is tied into that goal, and added that there needs to be better definition of how the tasks in this project will provide unique and necessary information towards that goal though.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the funding seems heavily weighted between SNL and UW at five times to one, while the project is presented as almost an equal share, with SNL taking data and UW using it to improve a code. It was stated that perhaps a more equitable distribution commensurate with the importance of these two broad efforts would be relevant.

Reviewer 2:

The reviewer commented that the funding level appears appropriate for the level of work required and planned.

Low-Temperature Gasoline Combustion (LTGC) Engine Research: John Dec (Sandia National Laboratories) - ace004

Presenter

John Dec, Sandia National Laboratories.

Reviewer Sample Size

A total of four reviewers evaluated this project.

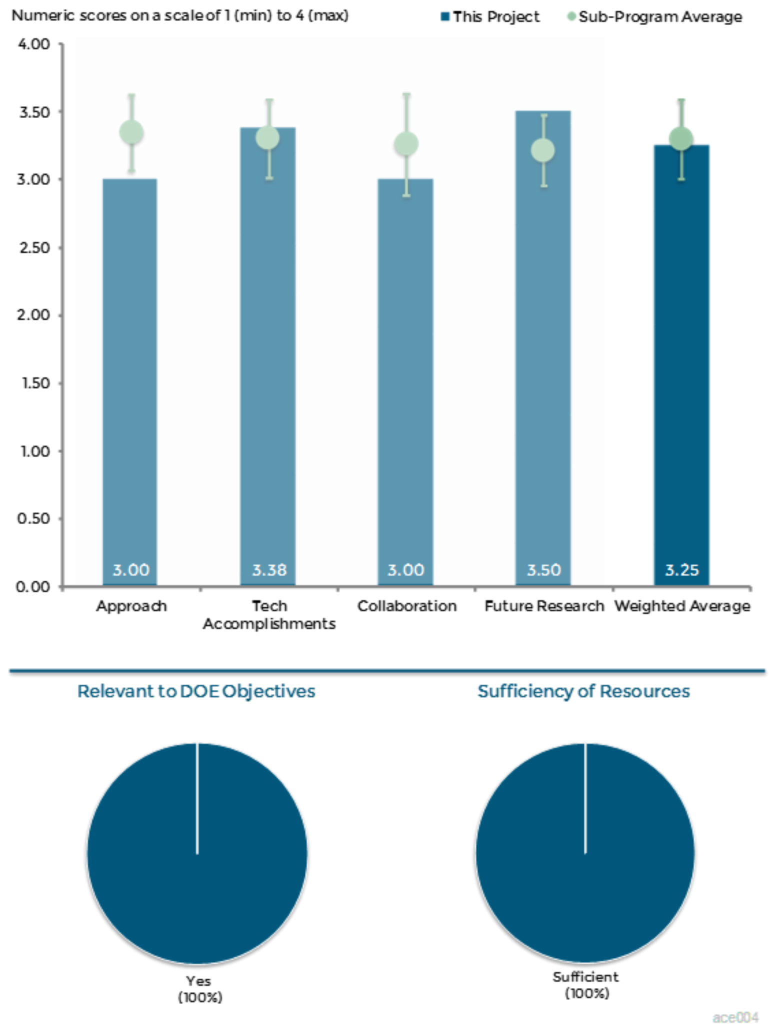

Figure 4-3 Low-Temperature Gasoline Combustion (LTGC) Engine Research: John Dec (Sandia National Laboratories) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer expressed an agreement that there is a full suite of techniques to address barriers, but suggested that there is a need to add combustion noise to ringing intensity metric as measure of combustion quality.

Reviewer 2:

The reviewer recommended that there should be much more emphasis on SI dilute combustion and to accelerate implantation of dual plug head.

Reviewer 3:

The reviewer indicated that continued improvements in indicated efficiency are interesting, but questioned what the PI expects for brake thermal efficiency considering the high boost pressure on a multi-cylinder metal engine. The reviewer then expressed a concern that the boosting required will be difficult with low temperature exhaust due to the lean mixture and high indicated thermal efficiency.

Reviewer 4:

The reviewer observed a combined effort of single cylinder engine testing and analysis to enhance fundamental understanding of fuel energy distribution in the IC engine process and multi-DI fueling strategies.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer acknowledged that project team has great progress toward further improvements in indicated efficiency. Concerning eventual implementation of the combustion concept, the reviewer questioned what impact will variations in commercially available gasoline have on the engine performance.

Reviewer 2:

The reviewer remarked that there were interesting results related to energy distribution analysis with respect to various parameter sweeps, and added that a knock onset indicator was developed. In addition, double DI partial fuel injection was studied in detail with regards to timing and fueling ratio and the impact on peak thermal efficiency. It was suggested CA50 controls methodology development from such studies are imperative.

Reviewer 3:

The reviewer commented that delaying spark assist; low charge motion cylinder head by a full year, for DI partial fuel stratification (PFS) work, seems long.

Reviewer 4:

The reviewer questioned if ringing intensity is being used as a noise or combustion quality metric, and noted that a comment was made that the project would benefit from a P-diagram to show the control and noise factors and how each is being addressed. The reviewer concluded that this would help understand the long term viability of the approach.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer remarked that there is outstanding collaboration throughout AEC, industry partners, universities and national laboratories.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer suggested that the DI-PFS strategies should be tied into a CA50 control strategy from the physical understandings gained from this project, and added that a simple prototype controller hardware can be used in such an investigation or development.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that all the fundamental research to understand energy distribution and DI-PFS strategies are crucial to enhancing engine efficiencies.

Reviewer 2:

The reviewer reported that this approach might result in improved engine efficiency, but only if it is proven on a brake basis with a real boosting system.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

There were no reviewer comments on resources.

Spray Combustion Cross-Cut Engine Research: Lyle Pickett (Sandia National Laboratories) - ace005

Presenter

Lyle Pickett, Sandia National Laboratories.

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

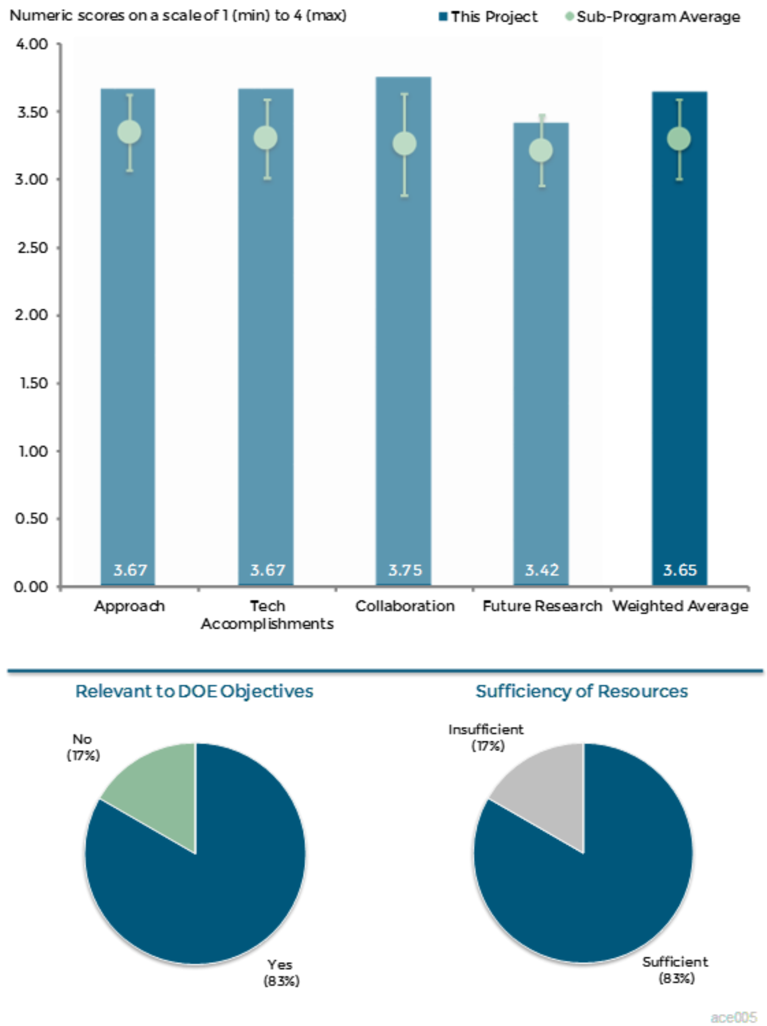

Figure 4-4 Spray Combustion Cross-Cut Engine Research: Lyle Pickett (Sandia National Laboratories) – Advanced Combustion Engines

Reviewer 1:

The reviewer commented that overall, the approach was been excellent utilizing the PI's experimental capability along with those capabilities of various collaborators. There is still much to learn about post injection mixing behavior in light of its potential impact on in-cylinder soot formation and it would be helpful to connect such mixing observations to the formation of soot either or both experimentally or computationally.

Reviewer 2:

The reviewer noted that in many ways, the Engine Collaboration Network (ECN) is a brilliant concept which is a true, non-competitive collaboration that brings together national labs, universities, component suppliers, and engine makers. The ECN multiplies the investment that DOE puts into it many fold. The reviewer mentioned that the research conducted by SNL itself is quite good as well, providing crucial understanding and experimental benchmarks for this key engine technology area.

Reviewer 3:

The reviewer commented that the approach has been methodical and stepwise, progressively attacking unknown features of spray combustion. Past work with spray A has been very organized. The reviewer suggests that there is some challenge evident now with the variety of sprays which are or will be under study. The reviewer then remarked that all of the sprays are important for various aspects of the overall project, but bringing them together and making the findings into a coherent story will be challenging going forward.

Reviewer 4:

The reviewer mentioned that the constant volume high pressure high temperature, while having some limitations, offers some advantages like precise and accurate control of the boundary conditions and initial conditions of the experiment, and suggested that the tradeoff is worthwhile.

Reviewer 5:

The reviewer said that the Principal Investigator (PI) noted the importance of improving engine efficiency which is believed to be gained by understanding direct-injection spray processes at engine-relevant conditions, and the CFD modeling of it. The reviewer then commented that there is little argument that spray quality will impact fuel economy and efficiency, in a broad sense. The challenge, however, is to establish a quantitative link, and this presentation did not do that. The reviewer pointed out that the importance of the approach was cast in more general terms as the need to do experiments at high pressures, understanding of the behavior of liquid in a high pressure environment, the process by which ligaments form droplets and knowing how spray cone angle varies with time. The reviewer also pointed out that all of which are qualitatively important but the quantitative connection to engine efficiency was somewhat deficient. For example, the reviewer questioned how is the gas solubility effect in a liquid fuel (droplet) that accompanies injection into a high pressure gas related to engine efficiency. The reviewer commented that in this reporting period the experimental approach appeared to be to use a constant volume chamber for imaging a spray and some interesting results were presented, and added that the environment of an engine is highly transient though and questioned if there are considerations with the constant volume results that prohibit carry-over to the environment of an engine. It was explained that this presentation would have benefitted mentioning some prior high pressure spray experiments that had been previously reported. Such information would have helped place this study in the context of the prior literature. This reviewer then suggested that asking such questions as what is new, what conditions have been previously examined, and how does the present study extend the prior art would be useful to have answers to.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the technical accomplishments pertaining toward single versus multi-hole nozzle spray behavior and post injection mixing has been impressive to date. There is still much more work to be done in order to extrapolate these findings to injector design, nozzle choice, and injection timing strategy. This reviewer then suggested that exploring past work on single versus multiple guided needles to better control hole-to-hole spray injection rate profile and to consider the presence of an impingement surface on post injection droplet or blob behavior from a wall wetting or near wall combustion behavior perspective.

Reviewer 2:

The reviewer noted that high-speed photo microscopic movies are very impressive indeed. The behavior of surface tension is very interesting in the transition regime. This reviewer claimed that these data and images will certainly help the modelers. It was mentioned the amount of progress made on Spray G and gasoline sprays was disappointing. The reviewer then questioned what can be done to speed up doing more experiments of interest to industry with Spray G or some other gasoline direct injection spray.

Reviewer 3:

The reviewer observed that the supercritical findings are fascinating, and should be of high interest when viewed in combination with multiple injection strategies for DI engines. The reviewer expressed suspicion that it will take some time before the results are fully interpreted since there is quite a bit there to understand. The reviewer expressed an encouragement for more investigation and discussion of the multi-plume verse single-plume experiments, and mentioned that there is an increasing body of evidence that there is significant plume-to-plume variability which impacts the cylinder performance and emissions, and as CFD results move towards higher predictively and fidelity, understanding how to capture those effects will be of increasing importance.

The reviewer also expressed an interest to see more time and budget devoted to the GDI spray. While there is more decoupling between the spray and combustion in a stoichiometric SI engine, the huge market size and petroleum use of SI means that there is a significant need to push the technology for these engines.

Reviewer 4:

The reviewer agreed that the reported results clearly show that fuel transition from liquid to gas phase under modern in-cylinder conditions is far more complicated than the traditional evaporation construct would suggest. Fortunately, modeling is beginning to catch up, but these descriptions need further quantification and incorporation into the tools that combustion system designers can use on a routine basis (i.e., without recourse to massively parallel computing that still takes weeks to complete one run).

Reviewer 5:

The reviewer remarked that the images showed the apparent disappearance of the liquid/vapor interface. Perhaps the PI can envision more controlled experiments for individual droplets that will allow better access to the multiphase boundary and how it might disappear. This reviewer then commented that a context with the prior literature would help here. The behavior of liquids in supercritical conditions is somewhat known, though perhaps not in the context of sprays. It was brought to light that aspects like increased gas solubility, disappearance of the interface and surface tension going to zero are all known concepts. The reviewer mentioned that it was noted that the ligaments ultimately formed spherical droplets after some deformation and oscillations. This reviewer questioned if these oscillations are more pronounced at high pressure, and if so why. The reviewer noted that it is quite interesting that much was made of tracking some individual hexadecane droplets injected into a supercritical environment (900K, 60bar) ambience. The reviewer asks if the PI can comment about the phase boundary that was apparent in his images. Additionally, this reviewer questioned if the fuzziness was the result of out-of-focus images or was it due to transitions through a supercritical environment where surface tension disappears. The reviewer then pointed out that the challenge with the experiments is how to extract quantitative information from them. It was observed the data obtained were somewhat qualitative, though apparently consistent with some prior published SNL simulations (Dahms and Oefelein, 2013). This reviewer then explained that the challenge is how to fold the results of these experiments into the framework of the ECN, where modeling work is being pursued among the partners.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer said that the ECN has been a huge push to the spray combustion community and provides outstanding coordination with a wide range of researchers, engine manufacturers, and suppliers.

Reviewer 2:

The reviewer mentioned that the collaboration appears good in all directions including government, academia, and industry. Additional collaboration with code vendors to get the technology out of the labs and into the commercial tools is encouraged.

Reviewer 3:

The reviewer commented that the engine combustion network continues to be an important collaboration for DI engine researchers around the world. This reviewer said that it is apparent the ECN has been an effective means to amplify the level of understanding pertaining to low and high pressure engine relevant sprays.

Reviewer 4:

The reviewer mentioned that the ECN, by nature of its philosophy, results in very good collaboration.

Reviewer 5:

The reviewer noted that the PI lists industry partners through an MOU, and collaborations with the ECN. This reviewer stated that the issue, if one could call it that, is precisely what is being developed by this project that those in the modeling community will need to validate predictive simulations for high pressure spray injection. The reviewer questioned what are the data and the measurements. It was explained there are some nice qualitative experimental results in this project, and the PI has a good command of the range of simulation capabilities being pursued. The challenge is to convey what the PI is developing that the collaborating modelers will need. The reviewer concluded this point should be strengthened in figure presentations. The reviewer indicated that the PI noted close collaborations that will lead to better CFD tools which presumably will be developed by those listed in the ECN who are pursuing development of no less than seven codes (e.g., KIVA, Converge, RAPTOR, Ansys, etc.). However, there are so many collaborators that it would seem almost unmanageable to work with them as a whole. Almost 30 groups are listed in the ECN, and the PI has noted the importance of his involvement with this group. The reviewer warned that it was not clear what the PI was delivering to the modelers and who among the group is working with the PI to use his data. The reviewer then concluded that this point should be strengthened in future presentations.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer expressed an overall agreement that the proposed future research is logical and provides a means to logically explore post injection mixing in high pressure jets and overall mixing behavior in low pressure sprays, and suggested that the PI consider exploring the impact of nozzle guiding options on hole-to-hole injection rate profile from miscible mixing and single versus multi-hole nozzle perspectives along with the potential impact of wall impingement on post injection mixing processes. The PI may also wish to consider lower chamber oxygen concentrations for future combustion experiments to explore the impact of potential miscible mixing on the combustion event including soot formation.

Reviewer 2:

The reviewer commented that the future work which includes development of a transparent nozzle assembly is interesting. However, the reviewer suggested the PI should scrutinize the literature to determine the extent to which such an approach may (or may not) have been pursued in the past to understand flow in the near nozzle region of a spray. The reviewer noted that an effort to study flash boiling is also mentioned but thought it is unclear what the PI has in mind. The reviewer explained an understanding of this process relies in part on the superheat/super saturation physics of liquids that arise for fluids that are in the metastable state, which also occurs during cavitation processes. It was recommended in future presentations the PI should establish more quantitative connections of how spray quality affects engine efficiency. This is necessary to maintain relevance of the work. This reviewer then indicated that it would require some full scale engine testing to employ things learned from fundamental spray studies to assess fuel economy benefits. The reviewer concluded that the science may be great, but if it doesn't translate to fuel economy gains the work will not have the desired impact for this program.

Reviewer 3:

The reviewer commented that there is a huge amount of work proposed between spray G, spray B, and sprays C/D, but would be concerned that too little will be done on each and that fewer topics with more depth may be better. This then expressed an agreement that all of the future topics are key and understands the balance is difficult.

Reviewer 4:

The reviewer mentioned that, to date, it appears that the focus has been on smaller injectors and it would be interesting to see the same sort of extensive study applied to heavy duty diesel injectors as well.

Reviewer 5:

The reviewer remarked that much more Spray G work needed.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated an agreement that this project supports DOE objectives by providing a potential future capability to design fuel injectors and combustion systems that enable combustion modes that ultimately reduce emissions while meeting Government fuel economy standards.

Reviewer 2:
The reviewer acknowledged that a better understanding of the injection of petroleum fuels in internal combustion engines (ICE) will lead to gains in efficiency through better designs and ultimately to reduction in fuel consumption.

Reviewer 3:
The reviewer observed that the PI notes the need to study the problem of engine efficiency from the perspective of gaining a fundamental understanding of sprays, mixing, multi-hole injection processes, pressure effects, and to collaborate with modelers working to simulate in-cylinder processes. This reviewer also stated that, beyond these broad considerations, a stronger link of each to fuel economy should be made. Doing so will assist the work by informing conditions and experiments on spray dynamics that should be performed.

Reviewer 4:
The reviewer noted that, as the PI said, the combustion system is driven by the spray so there is still an enormous need to understand the spray better both for the physical understanding as well as the modeling capability that will follow.

Reviewer 5:
The reviewer questioned if the ECN work is directly relatable to high efficiency engines, and also asked if the models that are being generated with ECN data directly relatable to high efficiency engine research and development. This connection has to be made in a clearer manner. Then reviewer then pointed out that the work is not relevant enough for LD fleet if more gasoline work is not performed.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer expressed a preference to see more funding to allow for more progress on gasoline direct injection (GDI) and conventional DI in parallel. This reviewer commented that the progress given the funding level is very good, but there is so much to do in this project.

Reviewer 2:
The reviewer reported that the collaborative nature of the research means much more results than the dollars going into the project alone can generate.

Reviewer 3:
The reviewer noted that this project appears to have a budget of almost $1 million, but stated that this does seem high given the issues of quantitative measurements noted previously. It was suggested some discussion in future presentations might assist the reviewers to better understand what this funding goes for, given that apparently the PI now has an experimental design up and running.

Reviewer 4:
This reviewer emphasized that the resources seem to be adequate for this type of applied research project.

Automotive Low-Temperature Gasoline Combustion Engine Research: Isaac Ekoto (Sandia National Laboratories) - ace006

Presenter

Isaac Ekoto, Sandia National Laboratories.

Reviewer Sample Size

A total of five reviewers evaluated this project.

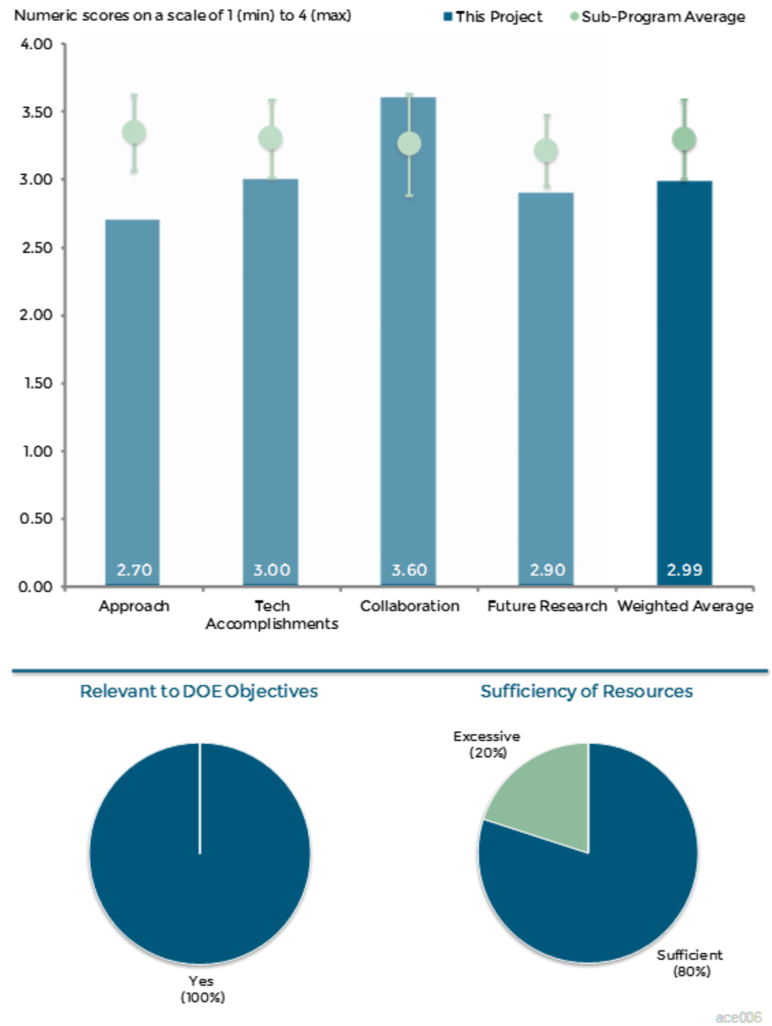

Figure 4-5 Automotive Low-Temperature Gasoline Combustion Engine Research: Isaac Ekoto (Sandia National Laboratories) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer agreed that multifunctional approach of using optical engine experiments, in cylinder diagnostics, and computer models is very good. It was commented that previous work has been done by others on negative valve overlap (NVO) and spark assisted compression ignition (SACI) and this work does not always seem to be beneficial to improving the viability of low-temperature combustion (LTC). This reviewer noted that it will be interesting to see whether the current work even when completed would significantly enhance the viability or benefits of those approaches.

Reviewer 2:

The reviewer remarked that the approach to analyze in-cylinder reformates created by NVO to enhance combustion is promising with the experimental capability and equipment available at SNL. This reviewer expressed an agreement that future effort on spark assisted compression ignition is an important topic.

Reviewer 3:

The reviewer mentioned that it is good that different fuels and their impact on NVO behavior are being looked at. The reviewer normally thinks of LTC as not having a flame front and commented it seems like a plasma igniter will initiate a flame and questions how this is considered LTC.

Reviewer 4:

The reviewer explained that the approach description is a bit generic making it hard to differentiate from other LTC approaches. This reviewer expressed a need to have more information on other researchers' use of NVO and how this approach differs.

Reviewer 5:

The reviewer pointed out that the barriers that this project claims to address are very broad and would like to see it the project team can be made more specific. The remark was made that this project seems to have many aspects to it and wonders if there is possibility to focus the project more.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer agrees that the progress is generally good with accomplishments that include completion of analysis of NVO end cycle detailed sample speciation data and analysis of the efficiency tradeoff between oxidation and reforming dominated NVO cycles. It was noted that some equipment was purchased for the O-atom laser-induced fluorescence (LIF) experiments.

Reviewer 2:

The reviewer remarked that there has been a good accomplishment of understanding reformate speciation.

Reviewer 3:

The reviewer remarked that there were interesting results from the NVO oxidation and reforming. It was questioned what the maximum load is that the engine can achieve with an NVO valve train. The reviewer commented that energy balance pathways are a good approach to explain behavior. This reviewer also expressed a need to see more results on the ignition system testing.

Reviewer 4:

The reviewer observed that good progress in understanding NVO as enabler for LTC, but indicated that it is not clear what the impact on overall brake thermal efficiency (BTE) or net thermal efficiency will be when this method is employed.

Reviewer 5:

The reviewer commented that it seems like the rate of progress is slow, but questioned what can be done to speed up getting the work done. The reviewer noticed that it has been two years since the ignition work has been proposed, but the old NVO work seems to still be taking up the major effort.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer said that it looks like there are collaborations with the three U.S. automakers (GM, Ford, & Chrysler), two lab specialty equipment manufacturers, three universities (USC, University of Minnesota, and University of Edinburgh) and the other national laboratories.

Reviewer 2:

The reviewer mentioned that it is good to see industry involved.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer indicated that future work to determine whether the use of NVO and/or SACI can significantly improve low-load low temperature gas combustion (LTGC) operating conditions is important.

Reviewer 2:

The reviewer mentioned that future work on SACI or laser induced ignition would be interesting to look forward to.

Reviewer 3:

The reviewer commented that it seems like there has been scope creep on this project, but questioned why the particle image velocimetry (PIV) work was added for the Argonne National Laboratory (ANL) ignition modeling effort. Also there is concern the proposed negative valve overlap (NVO) work with the Fuels for Advanced Combustion Engines (FACE) fuels could take up a lot of time. This reviewer then questioned if there is industry interest in doing this work and how the priority for the work is set.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer remarked that the program objective of enhancing fundamental understanding of LTGC processes for development of clean, fuel efficient engines supports DOE objective of improving fuel economy which leads to reduced use of petroleum.

Reviewer 2:

The reviewer indicated that alternative ignition approaches are of interest to industry.

Reviewer 3:

The reviewer said that this project addresses barriers for advanced combustion regimes.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

There were no reviewer comments on resources.

Large Eddy Simulation (LES) Applied to Advanced Engine Combustion Research: Joe Oefelein (Sandia National Laboratories) - ace007

Presenter

Joe Oefelein, Sandia National Laboratories.

Reviewer Sample Size

A total of five reviewers evaluated this project.

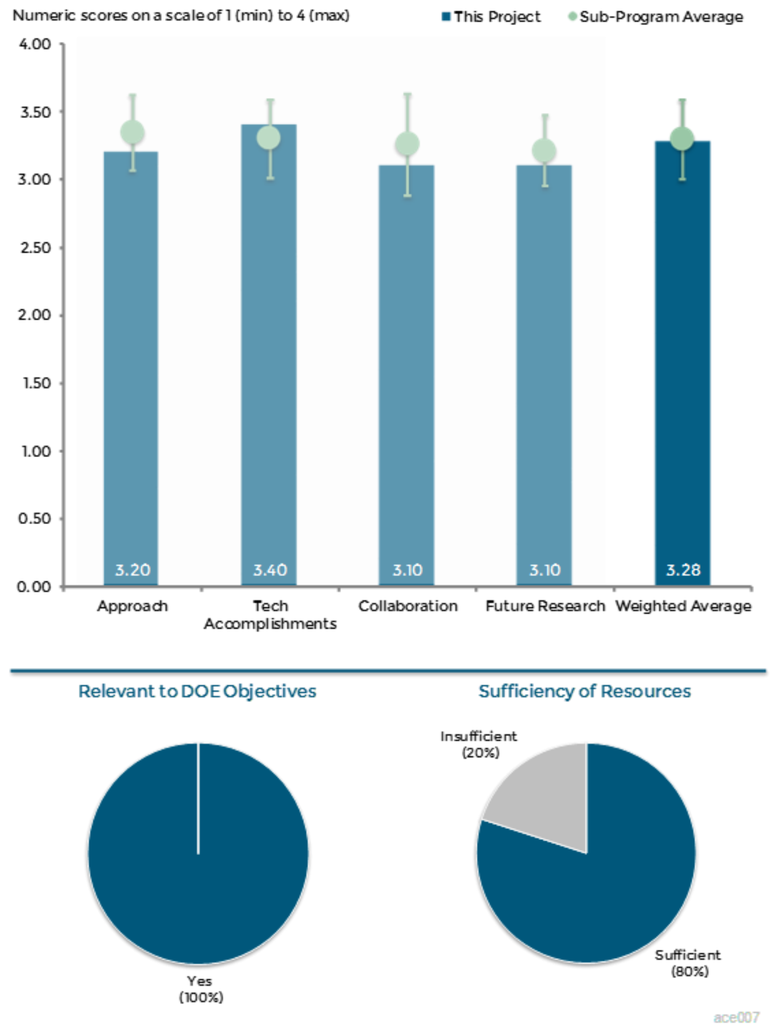

Figure 4-6 Large Eddy Simulation (LES) Applied to Advanced Engine Combustion Research: Joe Oefelein (Sandia National Laboratories) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that the project and approach are very important. The current CFD codes are useful but still have significant limitations in truly capturing the physics and chemistry of engine combustion. It was indicated the challenge of the project is that by definition it will be well in advance of where it is immediately useful to the industry, which limits its ability to be fully tied into fixing the barriers and having immediate impact on the challenges DOE is addressing.

Reviewer 2:

The reviewer said that the project is interesting work that tackles the issues, particularly with respect to contributions of turbulence, sprays, and combustion from a fundamental standpoint. This reviewer expressed and interest to see more extension into all up engine modeling to see where all this leads, and to see some serious coordination and communication with the commercial code vendors who will ultimately have to produce tools that can make use of this detailed knowledge to improve engineering simulations that actually design better engines.

Reviewer 3:

The reviewer that commented current and past work has focused on free jets at low pressure using constant volume vessel experiments to aid in modeling approach and development, but suggested that it would be helpful to sooner than later attempt using the free jet approach in a real world combustion device that accounts for wall effects and heat transfer. It is recognized that chemistry is still an issue, but the empiricism associated with matching real world engine measurements might end up dominating the end results which is a fair reason to accelerate comparison to engine experiments.

Reviewer 4:

The reviewer noted that this project concerns development of a computer simulation capability for ICEs (the RAPTOR code). It has certain features that separate it from other simulation capabilities (i.e., massively parallel programming; based on a large eddy simulation). The PI noted some challenges such as the high nonlinearity of the equations involved and the multiphase physics that need to be included. The reviewer reported that there is a lot of potential with this approach to simulating combustion engine performance. The reviewer stated that the list of challenges noted in the presentation did not seem to include a potentially important consideration, which is the coupling between in-cylinder transport dynamics and material stresses that are developed as a result of the engine block being subjected to high temperatures and pressures, and transient cycles of these variables during operation, but commented that detailed numerical predictions of in-cylinder processes apparently do not traditionally, but should consider the role of properties of the solid materials that the engines are fabricated from. It was indicated material failure considerations will impact durability and performance. Operation at optimal conditions identified from CFD modeling that neglect a material stress consideration may conceivably only be sustained for limited periods before material failure. The reviewer suggested that some consideration of this matter should be given in the project. The reviewer noted that there are a number of codes currently being developed by other national laboratories (including SNL) for predicting engine performance including Converge, KIVA, Open Foam, Star CD, etc. It was mentioned this project should place RAPTOR in the context of these other codes that ostensibly will claim an ability to predict the same sorts of things that RAPTOR can.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that in terms of project accomplishments within the scope of what it can address, the project has had some fantastic accomplishments. The modeling results which can be tied back to experiments by Musculus and Pickett are hugely exciting and will be a great addition to building the conceptual models of DI combustion. This reviewer concluded that it still appears that the models are well away from simulating a full engine system, so there is plenty of progress still to be had.

Reviewer 2:

The reviewer indicated that, at a fundamental level, there is some great research here, particularly on the role of real fluids during injection, turbulent mixing, and perhaps on the cusp of looking at combustion chemistry. While such a measured approach is good, the ultimate goal should be putting it all together in terms of engine simulations. Once that happens and it is shown to actually produce a better simulation of engine behavior, the scales may tip towards excellent research. The reviewer said that by taking it to the next step and directly impacting engineering level simulations that result in better engine designs, it will move to outstanding research.

Reviewer 3:

The reviewer noted that there has been good progress comparing the free jet direct numerical simulation (DNS) modeling approach with constant volume vessel measurements. These results are limited to free jets at this point in time. Progress has been a little slower than anticipated based on the past five years of work in this general R&D area. This reviewer pointed out that the engine community really needs to see progress made in conducting engine simulations in the near future.

Reviewer 4:

The reviewer highlighted that the work carried out included performing low eddy simulation (LES) simulations for spray A, and thought that spray A is presumably dodecane and spray G presumably means a gasoline spray which apparently was simulated by iso-octane. The data apparently come from constant volume and single cylinder engine experiments. The simulations included multicomponent thermodynamics and transport. The reviewer commented that the PIs are in the midst of carrying out simulations to quantify the effects of wall roughness, heat transfer on nozzle exit conditions, internal injector flow conditions, and are exploring the limits of combustion chemistry. A regime termed cool-flame ignition is noted. The reviewer questions if this is the same as LTC low temperature combustion. This reviewer also questioned how was the CFD regime identified and if the Sarathy, Narayanswami, and Luo kinetics include reactions related to CFD behavior. The reviewer explained that it was not clear precisely how sprays were handled by RAPTOR and asked if it has the capability to resolve individual droplets in a spray. The reviewer also questioned if the internal droplet transport in a spray coupled to the external spray (gas) transport. KIVA apparently provides this level of detail to resolve internal heat transfer within droplets and their evaporation, and their coupling to the region around the droplets. The reviewer questions if RAPTOR has this same capability. The reviewer commented that it is not surprising that there is a wide range of variability of predicted ignition delay times (IDT) between these mechanisms. The differences would appear even larger if the IDT data were presented on a linear scale. The reviewer concluded the more important question is what to do about it and asked if the PI has any thoughts. The reviewer commented the treatment of the GDI sprays was unclear, and then asked how the chemistry was handled, was a surrogate used and, if so, what was it. The reviewer also asked for the PI to please comment on the computational time. In addition, it was questioned if conditions are reached in the simulations where cavitation of flash boiling could occur upon the liquid exiting the nozzle and asked if RAPTOR can handle this situation.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer indicated that this project listed an enormous number of collaborators including over 30, either from national laboratories or academia, though the list did not seem to include industry partners. The project should provide more focus to these collaborations to make the team appear to be more focused and credible. Precisely what each of those listed brings to this project was unclear. The reviewer explained it would have been better to have a small number of collaborations that fill specific needs (e.g., data, simulations, sub-models, etc.) and provide specific inputs to the project.

Reviewer 2:

The reviewer said that the collaboration partners include both the ECN and various universities with expertise in engine CFD. This effort did outline utilizing ECN data to validate free jet LES spray formation predictions.

Reviewer 3:

The reviewer noted that there is definitely some good coordination within the government laboratories and with universities, but did not see much direct linkage to engine industry or software vendors to transition the technology and learning to them.

Reviewer 4:

The reviewer observed that this is a tough project for collaboration. The collaboration with other laboratories with complementary efforts is quite good, and it is obvious that other Combustion Research Facility (CRF) researchers are making use of this project as feasible. This reviewer also noted that there is very little collaboration with CFD tool companies and universities which may help to push advanced models towards more wide spread use, or end users. Admittedly, right now the models require computing resources that only the DOE has, so there is not much that could be done by these kinds of collaborators. Today's supercomputer will be a desktop machine in not too many years, so advance coordination now would be good for seeding the understanding of how to use these models. The reviewer suggested that some interaction with the ACEC technical team or some of the modelers at ANL or ORNL (in their engine groups) might be a good way to build those collaborations.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer indicated that the planned next steps look appropriate and are of high value, but would wish for faster progress, even though that is largely tied to computer availability and project funding. The pace proposed fits with those resource constraints.

Reviewer 2:

The reviewer expressed an agreement that the proposed research plan is fair. It would be helpful to pull forward simulation of optical engine experiments as a closer step to simulate metal engine in-cylinder behavior. The reviewer explained that it is not clear how this overall effort compares with LES work at ANL and if there is overlap or duplication.

Reviewer 3:

The reviewer commented that the future work mentioned essentially carrying out a range of simulation cases, including reacting flows associated with a GDI engine. The fuel used will be iso-octane, though ultimately the simulations need to transition to more complex multicomponent surrogates, which introduces a host of issues regarding chemistry and handling of transport properties.

The reviewer noted that other work mentioned includes carrying out LES of combustion to understand internal flow and model validation and in-cylinder simulations for LTC regimes to understand cycle to cycle variations.

Reviewer 4:

The reviewer pointed out that, while there is a lot planned, it looks like engine domain calculations are slated to begin in fiscal year 2017 and 2018 which seems a long way off.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer expressed an agreement that the development of a computational capability for ICEs is, of course, relevant. This project would benefit from placing the development or RAPTOR in the context of other widely used simulation capabilities which ostensibly will make the same claims made in this project regarding high fidelity predictions, low computation time and versatility.

Reviewer 2:

The reviewer mentioned that better understanding of in-cylinder behavior through better simulation methodologies will lead to more efficient engines that burn less petroleum.

Reviewer 3:

The reviewer pointed out that the project is somewhat out there relative to many of the other ones in the ACE portfolio, but this is a key area to invest in to advance our fundamental knowledge of combustion and the tools that will eventually be available for industry to use. The reviewer noted as the work continues and matures; it should support the petroleum use reduction well.

Reviewer 4:

The reviewer commented that this is a fundamental research project currently focused on modeling free jets that ultimately could be linked at a future date to the development of combustion systems most likely in low pressure combustion systems.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the project appears to be both limited in funding and progress on the central processing unit (CPU). This reviewer said that if more funding were available, it is apparent that more progress could be made.

Reviewer 2:

The reviewer noted that as a fully computational effort the budget of nearly $500,000 is probably adequate, when scaled with other projects at twice that which emphasize experiments.

Reviewer 3:

The reviewer stated that for the planned effort, the resources appear adequate.

Fuel Injection and Spray Research Using X-Ray Diagnostics: Christopher Powell (Argonne National Laboratory) - ace010

Presenter

Christopher Powell, Argonne National Laboratory.

Reviewer Sample Size

A total of four reviewers evaluated this project.

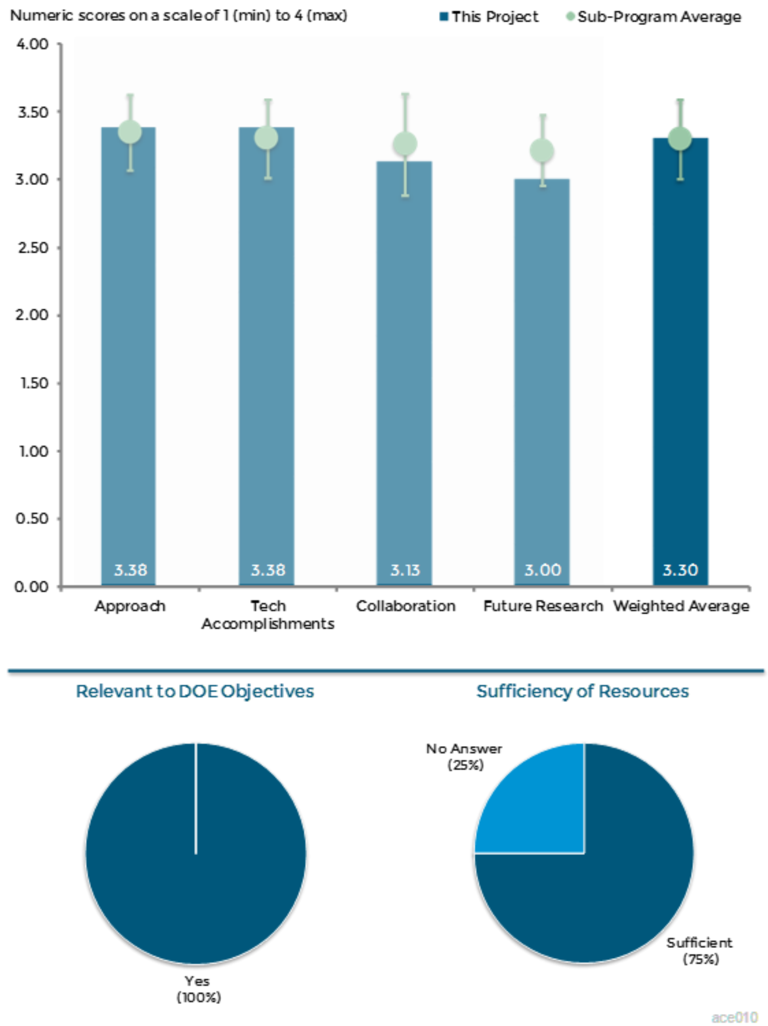

Figure 4-7 Fuel Injection and Spray Research Using X-Ray Diagnostics: Christopher Powell (Argonne National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the ongoing development of the x-ray technique is very good. The variability measurement/analysis for the CI spray is very interesting and does appear to have correlation with the mixing process. It was suggested more interaction with SNL on that aspect of the spray investigation would be of high interest to make sure the project team is interpreting the data properly. The reviewer indicated the addition of more GDI sprays is also good. A focus on how the lower pressure/higher volatility sprays differ from CI sprays will be an ongoing area of interest, especially the higher degree of variability in the quasi-steady portion of the spray. This reviewer expressed an excitement by the cavitation measurement capability. This is a long-needed imaging diagnostic. Any efforts which can increase the degree of similarity between the metal injector and the x-ray accessible hardware will be of highest value so that the cavitation measurements will be as valid as possible.

Reviewer 2:

The reviewer said that the application of the APS to study the injection process is a unique capability that is being exploited to better understand the complex physics involved to an extent not possible with other approaches that will be of particular importance in improving simulation capabilities for future ICE development.

Reviewer 3:

The reviewer commented that this project concerns developing an understanding of fuel injection processes to improve efficiency and emissions of engines. The approach involves using ANL's x-ray source to probe the structure of liquid jets in nozzles. This reviewer explained that the tasks are framed around making measurements for various test conditions. The purpose is to develop improved spray models. The reviewer noted that the approach of using the ANL facility is interesting as it provides the means to visualize, through metal, the spray structure. There are alternatives, such as using a nozzle design fabricated from a transparent material, such as plexiglass, for which there is some literature. The future work does mention real pressure transparent nozzle. The reviewer questioned what x-ray transparent means on the slides. The reviewer asked if it is the high pressures that make a transparent nozzle difficult to probe. This reviewer stated that it was not clear that useful information and at reduced cost could not be obtained with a suitable transparent injector design. The reviewer warned that the presentation itself was not clear on precisely what quantitative data was obtained in the reporting period. However, a lot of nice images were presented. The reviewer noted a need to go digging into some recent literature to find it, as well on the models used (e.g., Converge, OpenFOAM, HRM, etc.). This reviewer also noted that future presentations should be clearer on the data of interest and how modelers are using it.

Reviewer 4:

The reviewer encouraged that continued development of methods to evaluate gasoline sprays.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that there appears to be some very good progress on a few fronts this year. The improvements in the GDI imaging are very welcome and should pay dividends in the upcoming year, and noted that further analysis of how to make use of the variability should be of good value for the CI measurements. The cavitation measurements are really good and the reviewer hopes to see even more of this in the next year. The reviewer commented that the idea of imaging the spark is also very interesting. It is hard to tell how much of the ACE funding was devoted to that. It is something that would be of value if the imaging can provide additional information beyond what is available from electrical and visible light measurements. The reviewer suggested that some additional effort towards quantifying the possible value of this technique would be of use so that one can effectively evaluate the idea next year.

Reviewer 2:

The reviewer mentioned that the project has made several significant contributions in the diesel area and now appears to be making equally important measurements for GDI applications. Improvements in capability to make single shot measurements to help understand shot-to-shot variations will be particularly important for both GDI and diesel applications. This reviewer also indicated that expanding measurements to include droplet size will also be very useful, as will the ability to look at opening and closing transient effects.

Reviewer 3:

The reviewer indicated that the accomplishments reported for the past year included a lot of measurements and visualizations for the Army and modelers in the ECN. The PI also mentioned Sauter mean diameter (SMD) measurements. However, from what could be determined no such data were reported. The reviewer asked for this to be clarified. The efforts also involved completing a three-dimensional (3D) tomography arrangement that will allow measurement of the time-resolved density through the spray. The reviewer noted that one of the discoveries is that the spray has a high variability near the start of injection, and asked if this was surprising, and if so, why. The reviewer also wondered if it was the result of gas that may be trapped in the injector. The reviewer remarked the cavitation studies are interesting and was reported by the PI in a 2015 publication, and questioned if the PI has any strategies for reducing dissolved gas and cavitation. The reviewer asked in the simulation what cavitation threshold was assumed (i.e., pressure for a given temperature). The liquid is in a state of tension before it cavitates, and predictions will no doubt require knowing the thermodynamic state of the liquid that triggers cavitation. Also, the cavitation threshold is dependent on the dissolved gas content. The reviewer questioned how the PI's team estimate the dissolved gas content and predict the cavitation threshold. It was pointed out the PI notes contributions of data for the ECN, and asked precisely what data does the ECN need here. The use of the x-ray diagnostics to study ignition is interesting. Presumably it is by spark. The reviewer stated that it would appear to be very important to accurately measure the ignition energy, and suggested that the PI should provide some insights into how this could be done.

Reviewer 4:

The reviewer questioned if the measured spray variability is relevant when installed in a combustion chamber that has charge motion. It was suggested continuing emphasis on tying measurements to higher level engine attributes.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer remarked that the collaborative team is impressive including personnel with expertise in experiments and modeling. The collaboration with other colleagues at ANL (that employ Converge simulations) was clear, and noted that the role of the non-ANL collaborators was less well presented. For example, the PI does not state precisely what data are integral for the ECN network. The contributions of the academic partner were not clear on what was provided. Industrial contacts were mentioned but this is vague. The reviewer suggested it would help in future presentations to better show precisely what role the collaborators have. Providing results from the PI's efforts and quantitative input from the collaborators will be beneficial.

Reviewer 2:

The reviewer commented that the ECN interaction is very good, and certainly provides value to the ECN group, but would like to see more interaction with injector manufacturers beyond Bosch for the ANL work specifically. Also, it was indicated interaction with the engine groups at SNL or ORNL may also be valuable; to see how the findings from the APS imaging can be integrated back to the metal and optical engine work.

Reviewer 3:

The reviewer indicated that work with academic modelers and commercial code developers are very good, as is direct work with engine and injector makers.

Reviewer 4:

The reviewer stated that it is important to connect measurements to engine level attributes and encourage work with engine manufacturers/designers to make these connections.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer mentioned that the upcoming plans are very exciting, particularly the shot-to-shot work and the cavitation plans, and reported that both of these should increase the value and relevance of the work.

Reviewer 2:

The reviewer explained that the real fuel data is interesting but it cannot be simulated because one do not know their properties for inputs to validate codes. In particular things like combustion chemistry are not known and estimation methods for thermo-physical properties for real (multicomponent) fuels are not well established. The reviewer said that data for transportation fuel surrogates are more valuable for modelers because their combustion chemistry and physical property estimation methods are available (for judiciously selected gasoline and diesel surrogates). The issue should be important here because the PI notes the need for model validation with ECN partners. The reviewer suggested that the PI should consult Laurence Livermore National Laboratory (LLNL) for suggestions on a suitable surrogate(s) for their continuing work. The reviewer questioned what it meant when the PI stated “generate the temperature.” The reviewer stated that some of the plans for future work are a bit vague. For example, the PI notes the desire to build facility for high temperature sprays. This is unclear. This reviewer then asked if the PI envisions integrating the high temperature facility with the x-ray diagnostics. A clear need should be established here. The reviewer then noted that flash boiling of liquids is mentioned but the PI provides no elaboration on this process. Some of the same thermodynamic considerations involved with cavitation will also be relevant to flash boiling but these are not discussed. The reviewer remarked that the task for validation of LES simulations does not tell us much. The reviewer then questioned whose LES codes is being considered. SNL (Livermore) has a significant effort in this area (the RAPTOR code) but their contribution is unclear, though the PI lists SNL to assist development of improved spray models. The reviewer also questioned what data are needed and what capabilities does the PI have to deliver it. The reviewer commented that the future plan notes that the project team will have further measurements after consultation with experts. These experts are not identified so it is not clear. This reviewer questioned if the experts are part of the team or collaborators to be developed. The reviewer said that remaining challenges are noted that include pre-burn, shock tube, rapid compression machine (RCM) and Engine, but questioned what the PI is referring to here because it is hard to follow.

Reviewer 3:

The reviewer expressed an only concern is that expanding work to include GDI injectors will not adversely affect work on diesels, particularly measurements involving larger injectors used in heavy duty engines.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that the project is relevant because sprays set the initial conditions for fuel combustion in engines and this project is investigating the internal flow and atomization process in nozzles.

Reviewer 2:

The reviewer explained that understanding the spray physics is still key to improving both gasoline and diesel engines. The work in this project continues to develop ways to understand the sprays better and is providing new tools which are pushing into areas where there is great uncertainty in the spray physics.

Reviewer 3:

The reviewer stated that understanding injection is a key component in understanding ICEs. This reviewer concluded that better understanding leads to better designs which leads to higher efficiency and hence less petroleum consumption.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that it seems that the rate of progress and the funding level are well tied together and fit well with the overall program goals and desired rate of progress.

Reviewer 2:

The reviewer stated that resources seem reasonable.

Reviewer 3:

The reviewer said that the costs that are listed as being $775,000 for fiscal year 2015 seem high, but questioned if the costs are high due to costs of running the x-ray facility. The presentation did not give an appreciation for what is involved with such a large expenditure. It was suggested more should be provided to adequately assess this evaluation category.

Use of Low-Cetane Fuel to Enable Low-Temperature Combustion: Steve Ciatti (Argonne National Laboratory) - ace011

Presenter

Steve Ciatti, Argonne National Laboratory.

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

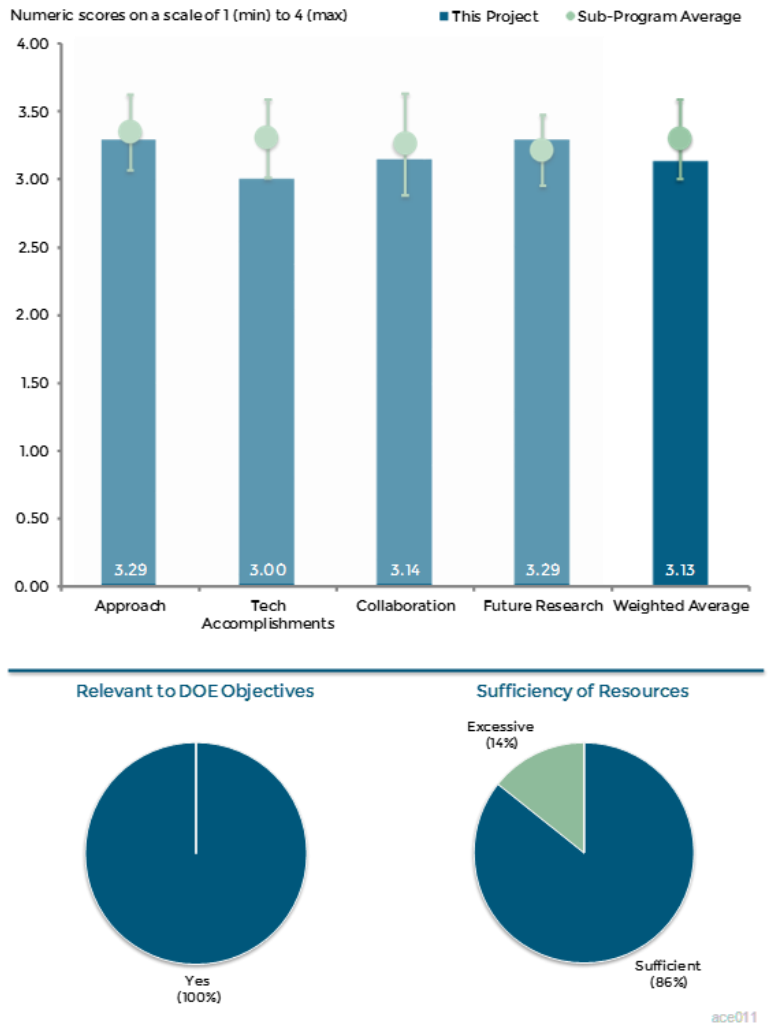

Figure 4-8 Use of Low-Cetane Fuel to Enable Low-Temperature Combustion: Steve Ciatti (Argonne National Laboratory) – Advanced Combustion Engines

Reviewer 1:

The reviewer reported that this project is an excellent combination of experimental and computational tasks. The former experimental work has been excellent to date. The only suggestion is to explore wider engine operating conditions closer to a real engine-transmission combination in a LD vehicle.

Reviewer 2:

The reviewer commented that this is excellent fundamental work to understand gasoline compression ignition in MCE, both experimentally and numerically. It was explained that advanced in-cylinder imaging and simulation work were used to study the auto-ignition process and soot distribution of gasoline compression ignition (GCI). Advanced imaging is a good way to investigate soot particle size distribution and number; it might be helpful to better describe the methods for determining the particle size and number when doing the post-processing of the images. If the results shown on Slides seven and eight for GCI and conventional diesel combustion (CDC) were produced from the same engine, the reviewer questioned if it is possible that the low soot luminosity for GCI is due to the leftover product of diesel combustion (for example, soot from diesel combustion). This reviewer then stated the results on Slide 15 are very encouraging.

Reviewer 3:

The reviewer commented that LTC has promise for significant efficiency improvements. This work provides understanding of the benefits and challenges of one recipe for LTC.

Reviewer 4:

The reviewer remarked that LTC control is with GCI in MCEs.

Reviewer 5:

The reviewer noted that the general plans for the project are good at attempting to address the challenges with GCI combustion. There are some significant holes evident in the approach though, or at least in how it is presented.

The reviewer explained that engine-out and tailpipe-out emissions are key. It is well understood that a GCI engine can be quite efficient. Different combustion approaches can change how much of a challenge hydrocarbon (HC) and carbon monoxide (CO) are, but there will always be emissions and these challenges will always need to be addressed. Beyond the availability or lack of low-temperature aftertreatment, there needs to be continued reporting on the engine-out emissions whenever the efficiency/brake specific fuel consumption (BSFC)/fuel economy is discussed. An estimate of the efficiency penalty to meet Tier 3/LEV III is also critical to fairly evaluate the combustion system. This reviewer also stated it is very unclear why there is so much endoscopic imaging as part of an MCE study. The capabilities at SNL to focus on the combustion chemistry and physics are so much more complete; if imaging is needed it should be funded and addressed there instead of on this project. The reviewer commented that using Autonomie is fine, but if it does not also provide estimates of drive cycle emissions then it is only partially useful; efficiency that the U.S. Environmental Protection Agency (EPA) will not allow on the road does us no good.

Reviewer 6:

The reviewer noted that there is a need to address robustness to noise factors in the research. It seems a key barrier to implementation of the technique is robustness.

Reviewer 7:

The reviewer explained that the tools used in this project are not novel, but similar to those in other projects such as endoscopic imaging of soot, operation of an MCE and simulation work.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that overall, there has been excellent technical progress. The only suggestion is to further study possible use of exhaust gas recirculation (EGR) as a lever to control and maybe widen the operating limits of the engine as indicative of LD type powertrain.

Reviewer 2:

The reviewer mentioned good progress has been made against the objectives of the program. The comparison of soot imaging between GCI and CDC is very encouraging. The reviewer suggested if it has not been done already, it might be helpful to compare the soot emission result from engine testing, and soot imaging first to make sure that they are matched, and then go for the measurement of particle size and numbers. The reviewer observed the results for injection timing and boost study are general. This reviewer suggested that a more in-depth analysis may be needed. It is also very important to show the results of other emissions, such as oxides of nitrogen (NO_x) and unburned hydrocarbons (UHC).

Reviewer 3:

The reviewer pointed out that the comparison of soot between GCI and diesel and the effect of swirl on smoke levels are both very interesting. The reviewer asked whether the “flash bulb or popcorn effect” in the simulation videos be explained because it is not imaged for one combustion cycle. The reviewer noted that the gasoline baseline used was a bigger engine. It is suggested that perhaps a downsizing effect ends up confounding the comparison and there may be a better apples-to-apples baseline available so only the advanced combustion performance can be assessed. The reviewer questioned how it compares when compared to a diesel baseline. Even though this comparison may have been published in earlier work, the reviewer suggests it may be useful to update it with the latest data or map and show the bottom line along with the gasoline baseline.

Reviewer 4:

The reviewer commented that the particle sizing work is good and of value, but a broader investigation of that would be highly valuable. This reviewer questioned if the particulate is all carbon, or does it still have significant solvent extractable fraction (SOF). The reviewer expressed an interested in what is the total PN emission from the engine. Filter soot numbers are not particularly valuable for this combustion system. The reviewer suggests that real particulate matter (PM) measurements per EPA accepted methods would be of higher value for evaluating the different approaches. It was noted there was no discussion of NO_x/CO/HC was presented and stated these should always be part of the discussion for the reviewers so one can see the full emissions picture of the engine. The reviewer indicated that there is a combination of running traditional parameter sweeps and then trying to discuss the results in terms of language that indicates that kinetic analyses or other computational studies were performed, but added that this weakens the presentation of the results and makes it harder to draw conclusions from the results. It was concluded the vehicle fuel economy results are rather meaningless if all of the engines are not meeting the same regulated emissions levels, and which are not obvious.

Reviewer 5:

The reviewer pointed out that there still seems to be a loose affiliation of directionally correct observations without an overall vision or pathway to a goal. This reviewer suggested a need to move past the characterizing phase and develop a pathway to completion. Essentially, the reviewer wants to know what success looks like. The reviewer said that the project needs to address the emissionability of the concept, and asked where the key challenges will be.

Reviewer 6:

The reviewer suggested that this project shares similar scope elements to other ACE projects and it is unclear how the results of these separate projects complimented one another as related to overall ACE subprogram objectives. For example, the GCI and soot particle diameter and particle number studies do not seem very different from those already reported by ORNL. The finding that injection timing and boost affect fuel reactivity has also been reported previously by John Dec and others. The reviewer said it was good to see shift to fuel containing 10% ethanol (E10), but results reported so far for E10 are not new.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer praised that the project of excellent teaming with lab, university, and industry partners. This reviewer indicated that it shows improvement from last year by bringing in UW, etc.

Reviewer 2:

The reviewer acknowledged that this project has outstanding collaboration with industry and universities and expressed that the project team did a great job. The reviewer indicated there are good partnerships with UW and University of California-Berkeley and there should be much more interaction with SNL or LLNL to make use of the fundamental capabilities there so that the work at ANL can focus on what ought to be done with an MCE.

Reviewer 3:

The reviewer reported that some limited interaction with auto industry reported (GM) and also interactions with two universities.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that future work is reasonable extension of present study. More work at different engine speeds and loads is very important for an MCE because this will ensure that all the conclusions still stand at high load and speed. High load is pretty challenging for LTC, more results in this area would be very interesting. The reviewer pointed out that another suggestion will be also to look at the effect of compression ratio on GCI engine performance, which may be very helpful for balancing the engine performance, engine control and emissions during engine design. The reviewer indicated that work needs to keep up the pace to meet the advertised milestones!

Reviewer 2:

The reviewer stated that proposed future research is logical. The only suggestion is to continue studies for widening the engine operational conditions.

Reviewer 3:

The reviewer acknowledged that adding EGR is useful for demonstrating a more complete control approach. This reviewer suggested that there should be much more focus on transient performance and full emissions so that the barriers for making a vehicle implementation of the technology can be evaluated better.

Reviewer 4:

The reviewer reported that there is a need to estimate HC and NO_x difficulties including cold start approach.

Reviewer 5:

The reviewer indicated that E10 should be the base fuel going forward. This reviewer also agreed that the planned work on characterizing transient performance with low pressure loop EGR will be very relevant, useful and interesting.

Reviewer 6:

The reviewer commented that it is unclear what distinguishes the proposed work from what has been done or will be done in other projects at other organizations.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that this is an excellent project exploring feasibility of DI gasoline for next generation high efficiency low emissions engines.

Reviewer 2:

The reviewer remarked that technology will significantly improve fuel efficiency and thus reduce petroleum dependence.

Reviewer 3:

The reviewer observed that a better understanding of the physical and chemistry characteristics of GCI with the goal of improving the development of high efficiency, low emissions engines supports DOE objectives.

Reviewer 4:

The reviewer commented that this project provides understanding on the benefits and limitations of LTC.

Reviewer 5:

The reviewer indicated that if GCI could be made to work; there should be some petroleum use benefit so there is potential in continuing to work on this technology.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that there appear to be sufficient resources, but there should be more leveraging of near-parallel work going on at other labs rather than trying to do so many things on this project alone.

Reviewer 2:
The reviewer observed sufficient resources.

Reviewer 3:
The reviewer recommended a review of project resources in relation to the overall ACE subprogram budget and objectives.

Model Development and Analysis of Clean and Efficient Engine Combustion: Russell Whitesides (Lawrence Livermore National Laboratory) - ace012

Presenter

Russell Whitesides, Lawrence Livermore National Laboratory.

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

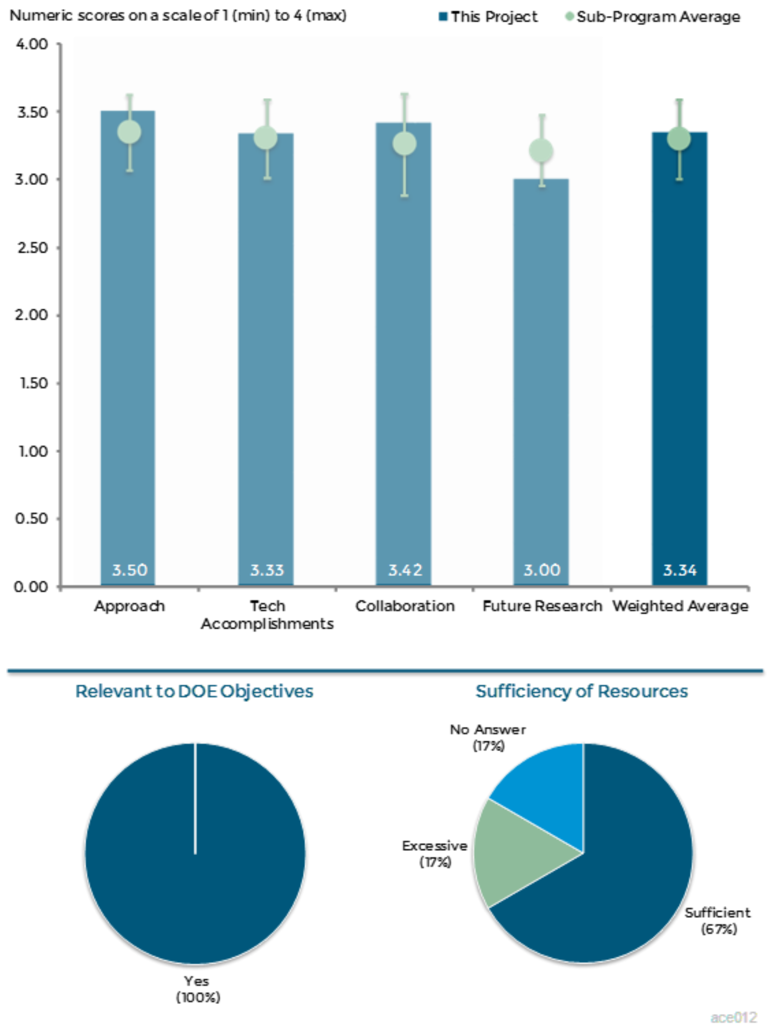

Figure 4-9 Model Development and Analysis of Clean and Efficient Engine Combustion: Russell Whitesides (Lawrence Livermore National Laboratory) – Advanced Combustion Engines

Reviewer 1:

The reviewer explained that, along with other LLNL projects, this work effectively aids the engine simulation community by developing a fast gpu-based chemistry solver for CFD applications. The approach of directly working with commercial code vendors and research code developers gets this technology in the hands of both industrial design teams and academic research groups and is to be highly commended.

Reviewer 2:

The reviewer commented that the work to speed up chemistry computations to enable higher fidelity kinetics as part of CFD is an important task. When this work first began, it was very exciting. At this point it is unclear what the long-term goal for the project is though. The big picture of what real limitations or shortcomings remain is missing. This reviewer pointed out that the uncertainty analysis is interesting, but just running it does not teach much. There needs to be significant work to interpret the results and to show why such a wide range of results could be obtained for a relatively small space of inputs for each variable. It was mentioned depending on the outcome of such an analysis; this could open up a new area of work that could be valuable.

Reviewer 3:

The reviewer indicated that the portion of the project focused on speeding up computational time for chemistry intensive solutions which is great work. The uncertainty example regarding key engine boundary conditions were very good too, but was limited to one medium load operating point. This reviewer suggested that more validation would be helpful in better understanding the predictability of the Converge code while running on advanced speed-up approaches.

Reviewer 4:

The reviewer remarked that the broad purpose of this project is to develop a predictive simulation capability for in-cylinder processes in an engine. The PI will incorporate detailed chemistry in the code. The reviewer pointed out there are several codes currently being developed as noted by the PI including Converge, KIVA, Open Foam, RAPTOR, Star CD, etc. As far as could be determined, the PI is seeking to improve the code's abilities to incorporate large numbers of reaction steps that will make them run more efficiently. This is being accomplished by development of a chemistry solver that could be integrated into the existing codes. The reviewer explained that the presentation appeared to assume that the audience already knew details of the chemistry solver, as the discussion presented results from it without really providing a substantive discussion of its ingredients. It was stated there is some overlap of this project with project ace076 that should be clarified. The reviewer agreed it is very good that the PI envisions bringing a predictive simulation capability to the desktop PC. This reviewer also stated that the success in this project would be significant.

Reviewer 5:

The reviewer questioned if there is a way to incorporate soot emissions in the predictions.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that progress on speeding up computational time frames has been outstanding to date. Validation is still lacking for the convergent code. The illustrative uncertainty example was helpful, but much more work is necessary to better quantify the predictive capability of the Converge code.

Reviewer 2:

The reviewer stated that improvements in computation time eventually enabling calculations to be performed on a PC is good provided accuracy not compromised. Sensitivity analysis to validate model results with experimental results is good.

Reviewer 3:

The reviewer indicated that the approach has been demonstrated and is beginning to be applied to engine simulations. Uncertainty and sensitivity analyses of homogeneous charge compression ignition (HCCI) problem are noteworthy, but commented that the speedup achieved with using graphics processing unit (GPU) is impressive but quantitative comparisons of predictions with using CPU versus GPU should be shown. The reviewer suggested that more validations and comparisons of model predictions with experimental data are needed

Reviewer 4:

The reviewer commented that the work carried out over the past year includes developing simulations (including uncertainty and sensitivity analysis) for a range of in-cylinder conditions, with HCCI and premixed charge compression ignition (PCCI) modes being a focus, and also stated that the PI developed a chemistry interface for coupling to several CFD packages. Converge seems to be the main package considered. The reviewer asked if the PI can please comment if the chemistry solver will be adaptable to KIVA. The reviewer noted that an improvement of between two to four times was noted for some small mechanisms (48 species for iso-octane is mentioned), and suggested that it would help to cast this improvement into actual computational time. The reviewer stated that the emphasis seems to be on smaller mechanisms as it is apparently not cost effective for large mechanisms which are a reasonable perspective. That said, there are other groups which seem to be incorporating large reaction mechanisms in their simulations. For example in project ace007 RAPTOR simulations of ignition delay time were reported using almost 3,000 reactions for dodecane. It was suggested it would help to place the performance of the chemistry solver in RAPTOR or other codes in the context of the chemistry solver being developed here. The reviewer then commented that that perhaps the PI could use Converge to predict ignition delay times from his chemistry solver to compare.

Reviewer 5:

The reviewer stated that it is very unclear from the presentation if the technical accomplishments were a major challenge or not. This reviewer then mentioned that more discussion of what was required to make the speedups and more in depth analysis of the HCCI results are needed.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer noted that collaboration with industry partners and universities seems fairly strong. It would be helpful if the engine OEM partner would aid more in validating the Converge code with IC engine data using the various speed-up routines.

Reviewer 2:

The reviewer commented that it is good the PI has on-going collaborations with the AEC working group, several industries, universities and national laboratories. However, what the collaborators provided to the project was unclear, as was the necessity of the expertise of some collaborators, but remarked that for the universities listed (i.e., University of California at Berkeley, UW, Clemson University, and San Francisco State University), there was no information provided on what they were bringing to this project or what substantive contribution they are making.

Reviewer 3:

The reviewer commented that the coordination with other researchers is good, though there are a number of programs all funded in ACE which could be better integrated including, KIVA, high fidelity LES, computational speedup, to make sure that the technologies developed by DOE work together and feed into needed improvements. The reviewer suggested that there also should be some interaction with the end-user industry. Part of the work DOE can be doing is to speed up simulations for what is currently done in industry, but part can also be making the tools faster and better for higher fidelity simulations. Without that interaction, there is little opportunity for impact.

Reviewer 4:

The reviewer reported that the collaboration with code vendors has already been noted, but should be expanded to include more. This reviewer also suggested that while some industrial partners are engaged, more need to be solicited to increase the scale of testing against real engine problems to continue validation and performance testing.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that the project listed a number of challenges that will form the basis of future work. These included reducing the cost of CFD, that real fuel (and by that term is assumed to mean surrogate chemistry mechanisms are large and therefore costly so that computational time needs to be reduced, and that it is still an outstanding matter to simulate chemically reacting spray dynamics when soot also forms. More specifically, the future work is framed around broad tasks that will seek to improve combustion chemistry and carry out engine simulations in collaboration with LLNL. This reviewer expressed an agreement that the plan for the future is reasonable, though presented in somewhat broad terms with few specifics. The reviewer suggested that some discussion of the possible overlap or distinction with the future work of ace076 should be provided.

Reviewer 2:

The reviewer said that the proposed future research is fair. It is lacking in experimental validation of the Converge code while running speed-up routines. The reviewer suggested much more effort should be spent validating the Converge code against constant volume vessel and IC engine data.

Reviewer 3:
The reviewer observed that future plans appear a little vague. Hopefully, more work with laboratories to validate, benchmark, and improve the approach while also trying to expand collaboration with engine industry and code developers and vendors is anticipated.

Reviewer 4:
The reviewer noted that the proposed work for CFD speedup looks much like what has already been done and questions what is truly new or left to do. The reviewer said that the uncertainty analysis has some good potential, but needs to be much more defined and much more detailed in execution/analysis.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that from a broad perspective this project involves developing a tool (chemistry solver) that will improve the ability to simulate performance of combustion engines. The particular approach of this project focuses on developing a chemistry solver that will more efficiently incorporate detailed chemistry in various engine simulators (e.g., Converge, KIVA, etc.). This reviewer also explained that since combustion chemistry is an important consideration in detailed modeling of engine performance, so too is development of tools that will efficiently solve the plethora of species diffusion equations that result from considering oxidation schemes that involve many reaction steps.

Reviewer 2:
The reviewer concluded that if the project is successful and gets faster chemistry into industry hands, then it should assist in developing higher efficiency engines.

Reviewer 3:
The reviewer explained that the project is relevant in so much as improved analysis capabilities will lead to improved engine designs with higher efficiencies and lower fuel consumption.

Reviewer 4:
The reviewer pointed out that this project can provide engine designers with a tool to develop tomorrow's future efficient engines.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that resources appear adequate.

Reviewer 2:
The reviewer pointed out that the results presented do not appear to be consistent with the amount of funding provided. This could be because the difficulty of the task is hard to appreciate but that needs to come across in the presentation.

Reviewer 3:
The reviewer explained that as a project that emphasizes simulation (without an experimental component) the budget at about $500,000 is in line with other studies of this type. However, the reviewer suggested that the results of the project should be reviewed in relation to project ace076 in terms of their combined contributions to ACE subprogram objectives.

Chemical Kinetic Models for Advanced Engine Combustion: Bill Pitz (Lawrence Livermore National Laboratory) - ace013

Presenter

Bill Pitz, Lawrence Livermore National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

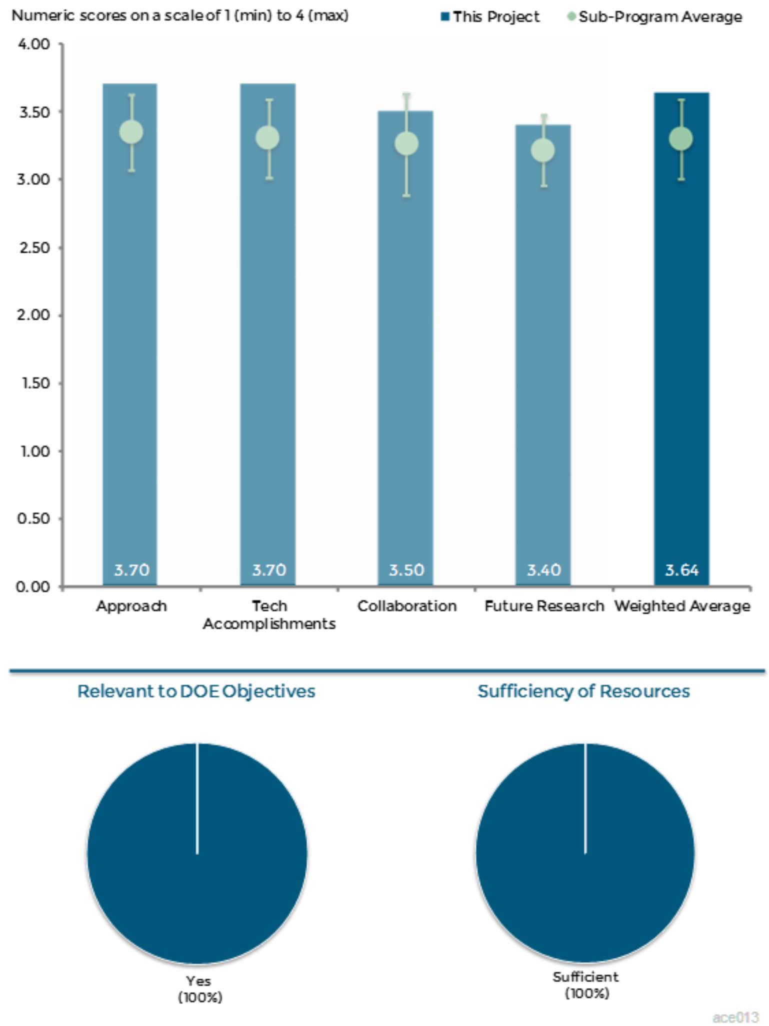

Figure 4-10 Chemical Kinetic Models for Advanced Engine Combustion: Bill Pitz (Lawrence Livermore National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that the approach for development of kinetic combustion models for key components present in gasoline, diesel and biofuels; combining them to form surrogate fuel mixtures; and development of reduced mechanisms and validation against experimental data from shock tube, rapid compression machines and jet-stirred reactors is extremely valuable.

Reviewer 2:

The reviewer noted that detailed chemistry mechanisms for fuels are the starting points for multi-dimensional engine simulations (granted there is a lot that has to happen, for example, mechanism reduction, before the mechanisms can be used, but still the detailed chemistry is the logical starting point). This reviewer added that the project has made significant contributions through their systematic development efforts over the years.

Reviewer 3:

The reviewer mentioned that this is critical work to improve the state of the art in engine simulation.

Reviewer 4:

The reviewer stated that development of kinetics models for engine fuels is important for combustion modeling purposes. There is also a need to bridge the gap between the chemists and the engine researchers though interactions and workshops. Maybe that needs to be added to the approach of this effort so that the scientists on both sides have a better understanding of what needs to be done and what can be done. Depending on the spatial and temporal resolution necessity of combustion CFD, the chemists can quickly bridge the gap between the fundamental detailed reaction mechanisms and reduced kinetics which can be modeled in a 3D CFD environment in a realistic CPU time.

Reviewer 5:
The reviewer observed that the approach is good, and agreed that chemical kinetic models are needed to aid in chemistry-based combustion calculations. Mechanisms are first validated against available shock-tube or RCM data, which is the best one can do.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that outstanding progress in developing mechanisms for new components and assembling into more robust models for surrogate gasoline and diesel fuels. Accomplishments include: improved low-temperature mechanism for n-butylcyclohexane and validation against shock tube data; development of mechanisms for seven of the nine components present in one of the Coordinating Research Council (CRC) Project 18 under the Advanced Vehicle Fuels/Lubricants of the Coordinating Research Council (AVFL-18) surrogate diesel fuels; development of a cyclopentane mechanism (one of the model components in gasoline surrogates); and development of a 10 component surrogate to match properties of CRC FACE gasolines.

Reviewer 2:
The reviewer commented that it was good to see additional component models for gasoline surrogates. This reviewer also praised the project team's great progress on additional component models.

Reviewer 3:
The reviewer pointed out that there was significant progress demonstrated in fiscal year 2015 in developing kinetics models for gasoline and diesel surrogates. These mechanisms were valid at 40 bars, which is a great progress. This reviewer then commented that the path to higher pressure kinetic calibrations seems to be undetermined. Much higher pressures are routine in ICE combustion.

Reviewer 4:
The reviewer indicated that good progress has been made in modeling several key diesel and gasoline mechanisms.

Reviewer 5:
The reviewer explained that getting mechanisms faster would be better, but it is ultimately more important to get the mechanisms right, so understand the progress can appear slow when in fact it is proceeding as fast as practicable.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:
The reviewer observed that the collaboration with industry, the national laboratories, and universities are outstanding. Unlike other projects, the collaboration with industry goes well beyond the two AEC MOU meetings per year, through active, regular engagement with the energy company and automaker members of the CRC AVFL Committee and FACE Working Group.

Reviewer 2:
The reviewer stated that the level of collaboration is extremely high as expected from a national laboratory. The project team is working together with all the stake holders in industry, universities and other national laboratories.

Reviewer 3:
The reviewer reported that good collaborations with other institutions to access raw data.

Reviewer 4:
A reasonable variety of collaborations with other laboratories, universities, and industrial partners is noted by the reviewer.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer indicated that there are excellent plans to continue the outstanding progress that has been made and to continue to advance the program goals.

Reviewer 2:
The reviewer explained that the proposed work logically builds and expands upon the work performed to date. This reviewer suggested that it would perhaps be useful to see more validation against engine data and case studies where industrial CFD users make successful application of the mechanisms developed so far (after appropriate reduction, etc.).

Reviewer 3:
The reviewer commented that future work is progressive towards overcoming challenges. It would be great to see some ICE CFD results using the reduced and detailed kinetics developed in this project, and a comparison with CFD where such accurate mechanisms were not available.

Reviewer 4:
The reviewer suggested that the work planned for modeling and validating gasoline surrogates is much needed and this work should be accelerated.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer pointed out that accurate kinetic mechanisms that are validated against experimental data is critical to successful design of improved, higher efficiency conventional and advanced combustion engines, which will lead to significant fuel economy improvements and lead to less petroleum usage.

Reviewer 2:
The reviewer remarked that better mechanisms supports better simulation which supports better, more efficient, engine designs which reduce petroleum consumption.

Reviewer 3:
The reviewer explained that chemistry models are fundamental requirements to improve engine simulations to design new engines that are more efficient.

Reviewer 4:
The reviewer responded that the project certainly supports DOE and agreed that developing accurate understanding and models of combustion kinetics is paramount to developing pathways to higher engine efficiencies.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer that appear adequate.

2015 KIVA-hpFE Development: A Robust and Accurate Engine Modeling Software: David Carrington (Los Alamos National Laboratory) - ace014

Presenter

David Carrington, Los Alamos National Laboratory.

Reviewer Sample Size

A total of six reviewers evaluated this project.

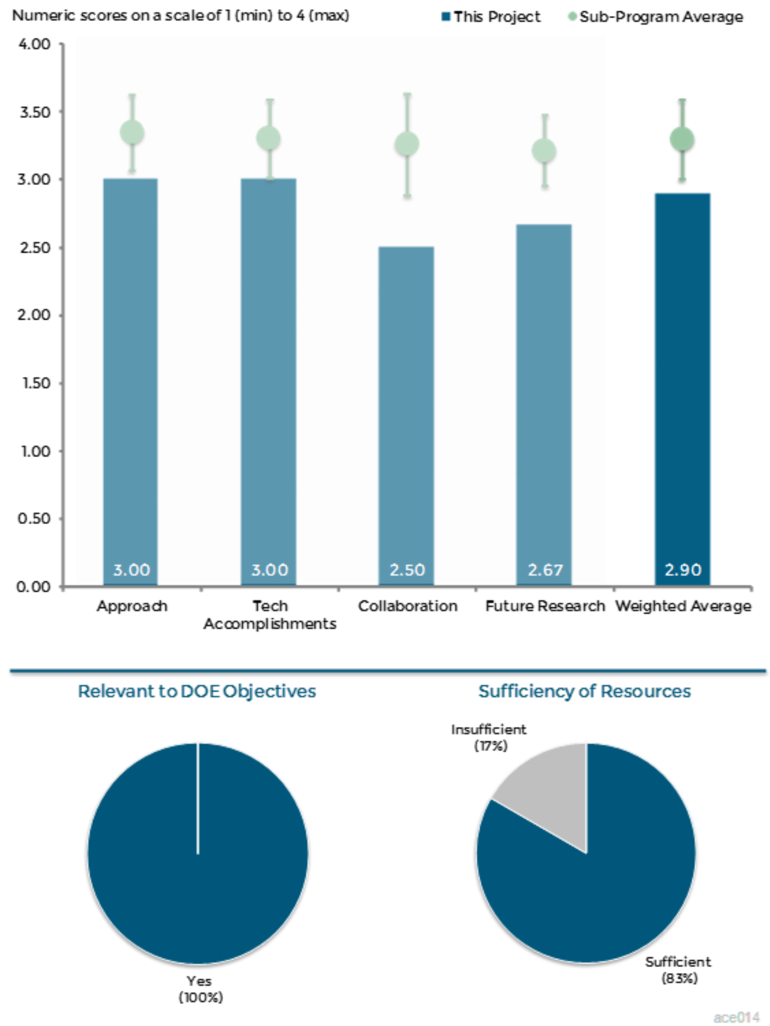

Figure 4-11 2015 KIVA-hpFE Development: A Robust and Accurate Engine Modeling Software: David Carrington (Los Alamos National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that the approach of further improving KIVA to make more robust and accurate predictions of fuel injection, fuel-air mixing and in cylinder combustion and emissions processes is very important.

Reviewer 2:

The reviewer observed that KIVA hpFE is a significant departure from previous finite volume codes. One clear advantage of this approach is in conjugate heat transfer calculations with surrounding walls of cylinder, head, and piston which can be calculated as one integrated analysis without recourse to heat transfer coefficients. The team appears to be incorporating higher order numerics for greater accuracy and working towards a code optimized for high performance computing (HPC) performance. Some improvements in physical modeling over existing codes also appear to be included. The reviewer warned what is missing is how all of this will get in the hands of engine designers who need well supported commercial tools, not research codes.

Reviewer 3:

The reviewer agreed that the approach has been fair, which is aimed at both addressing user issues with KIVA and improving meshing with overall computational efficiency of this legacy code, but explained it would be helpful to see more validation of suggested improved sub-models such as spray modeling, heat transfer, and turbulence modeling from either constant volume devices or engines as appropriate.

Reviewer 4:

The reviewer questioned what can be done to make KIVA more relevant to industry. At present, it really only used in academia and not in industry, but explained it is a good teaching and learning tool to develop student skills in CFD code and usage.

Reviewer 5:

The reviewer pointed out that it is very clear that the project team and lead is vested in enhancing and developing a next generation KIVA code capable of parallel processing and stated the cause is noble. However, it is unclear if this is a good roadmap to developing ICE CFD codes. Industry requires software support from commercial vendors, which national laboratories and universities cannot provide for open source or publicly funded CFD codes. Grid generation techniques eventually should be managed by commercial vendors even if early mathematical development is with laboratories and universities. Thermodynamic, fluid dynamics, and combustion models are where labs and universities can bring in a lot of expertise and validation. Even with those, a commercial spin-off is necessary to provide a support infrastructure and business which laboratories simply cannot provide. It seems there are quite a few leading ICE CFD vendors where a collaborative work could be the future. However, the reviewer expressed doubts about the approaches and accomplishment of this Los Alamos National Laboratory (LANL) led KIVA team.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that technical accomplishments demonstrated by standard CFD problems with the new KIVA code is excellent, including ability to do conjugate heat transfer, without requiring heat transfer coefficient calibration, and also computing speedup with parallelization. The reviewer wondered if the KIVA team will be up for leading a benchmarking effort for a rather simplistic ICE CFD example problem, against other popular commercial code. It was explained that it will be beneficial for the community to understand the pluses and minuses of various codes' capability, and also provide insight into areas where KIVA stands out. Currently that comparison is very subjective, and as a result code choice is based on personal preference rather than rational technical comparison.

Reviewer 2:

The reviewer noted that there appears to be very good progress. Notable accomplishments include better finite element model leading to better KIVA multi-spray model, more accurate droplet transport model and more accurate prediction of conjugate heat transfer in wall film and its effects on combustion and emissions.

Reviewer 3:

The reviewer mentioned that some of the technical accomplishments, like conjugate heat transfer, the ability to track error, etc., are very impressive. However, the reviewer commented rate of progress seems slow. Slide four shows it has been at least five to six years of KIVA-4 development. This reviewer then questioned if the technology is ready for release.

Reviewer 4:

The reviewer indicated that the code speed-up portion of the technology accomplishments discussion was evident. It was claimed that overall the spray model and heat transfer models were improved over the standard KIVA code though there was no evidence presented to substantiate those claims. This reviewer also questioned if the PI has compared the most recent KIVA code to actual spray chamber measurements or optical engine spray measurements.

Reviewer 5:

The reviewer pointed out that progress continues to be steady, but rather slow, but would have hoped that the code would be churning away demonstrating its superiority on real engine problems by now. The project is nearly over and the real validation work has yet to begin. To put it another way, many of the experimental projects are also developing new diagnostics technologies, but the project team is also applying them to answer questions concerning the physics of engine operation in existing and new regimes. One would expect that this project should be doing likewise.

Reviewer 6:
The reviewer stated that it is good to see improvements to grid generation. This had been a significant impediment to productivity in the past. Implementation of conjugate heat transfer is a very powerful addition.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:
The reviewer noted that partners and collaborators are mainly limited to co-developers which may be appropriate for this activity at this time.

Reviewer 2:
The reviewer pointed out that the team consists of LANL and a handful of universities, and questioned where the industrial partners are testing the code and its features on real world engine problems. The test cases to date, while important for validating the coding and methodology on comparatively simple, well defined problems, lack the real world engine problems that the code is ostensibly being designed for. Industrial partners would be very good in supplying real problems that need to be solved, giving the code a real workout for its intended purpose. The reviewer asked where the coordination with other government laboratories is. The proposed inclusion of LLNL's chemistry solver technology is a step in the right direction, but is lagging commercial software developers even on this point. Of course, the ultimate collaboration and coordination should be focused on getting this software and its technology out of the national laboratory and into the commercial software vendors who can turn it into the supported, easy-to-use tools needed by the engine industry.

Reviewer 3:
The reviewer warned that collaborations are limited to other CFD developers. This reviewer also suggested that it would be good to see some collaboration to validate CFD predictions with experimental results from engines.

Reviewer 4:
The reviewer noted that there has and is currently collaboration with a couple universities. It is questioned if it is possible other U.S.-based entities are interested in this current work effort who can aid in validating these recent changes to the various KIVA sub-models.

Reviewer 5:
The reviewer suggested that more collaboration or connection with other universities and national laboratories is required to understand why some of them have moved away from KIVA.

Reviewer 6:
The reviewer questioned that if the needs of industry are being considered and why industry is not using KIVA 4 and KIVA hpFE much.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the future goals set are very impressive as were the accomplishments this year. This reviewer also warned that some more synergy is required with other teams (including commercial vendors who are working closely with national laboratories to develop physical model). This reviewer expressed a concern about double work in the community. It is suggested that benchmarking leading codes with KIVA and presenting those results will help.

Reviewer 2:
The reviewer noted that the computational aspects of the proposed future research are very good. It is suggested more experimental validation should be part of future research to substantiate improvements to the various sub-models, including constant volume vessel and IC engine spray measurements.

Reviewer 3:
The reviewer acknowledged that plans seem to build on existing accomplishments and directed toward achieving program objectives.

Reviewer 4:
The reviewer recommended that the focus should be on business model of the latest KIVA versions so industry finds it attractive to use.

Reviewer 5:
The reviewer said that because the project is nearing completion, and a lot of development and a great deal of testing (with specifically engine problems) remains, the reviewer questioned if the timeline is realistic given the scope of what needs to be done.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that the development of improved simulators to model fuel injection, fuel-air mixing, and combustion and emission processes that are viable for use by the OEMs should enable faster development and commercialization of more efficient, lower emissions engines, which are consistent with DOE objectives.

Reviewer 2:
The reviewer commented that better analysis techniques will lead to better engine designs which lead to higher efficiencies and less petroleum consumed.

Reviewer 3:
The reviewer agreed that this project does support DOE goals by supplying engine designers with a potential tool to development future fuel efficient ICEs.

Reviewer 4:
This reviewer mentioned that KIVA is the hallmark of fundamental engine modeling. Its contribution in understanding engine physics is unquestionable.

Reviewer 5:
The reviewer stated that the project is relevant. However, this reviewer questioned if KIVA 4 and KIVA hpFE have a future. In addition the reviewer asked if it has been released, who are its customers and what the plan for support is.

Reviewer 6:
The reviewer explained that KIVA is not significantly used in industry, so it does not have a direct impact. However, there is an indirect impact in training CFD developers and users that can contribute to development of codes used in industry and for this reason it is important.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer warned that it will be a close call if everything can be delivered with the resources available, but willing to give the team the benefit of the doubt.

Reviewer 2:

The reviewer explained that to develop a user friendly code for engine design engineers; it appears that the human resource of KIVA is limited. Maybe a private partnership is required to retain the KIVA leadership in fundamental engine modeling.

Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes: Stuart Daw (Oak Ridge National Laboratory) - ace015

Presenter

James Szybist, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

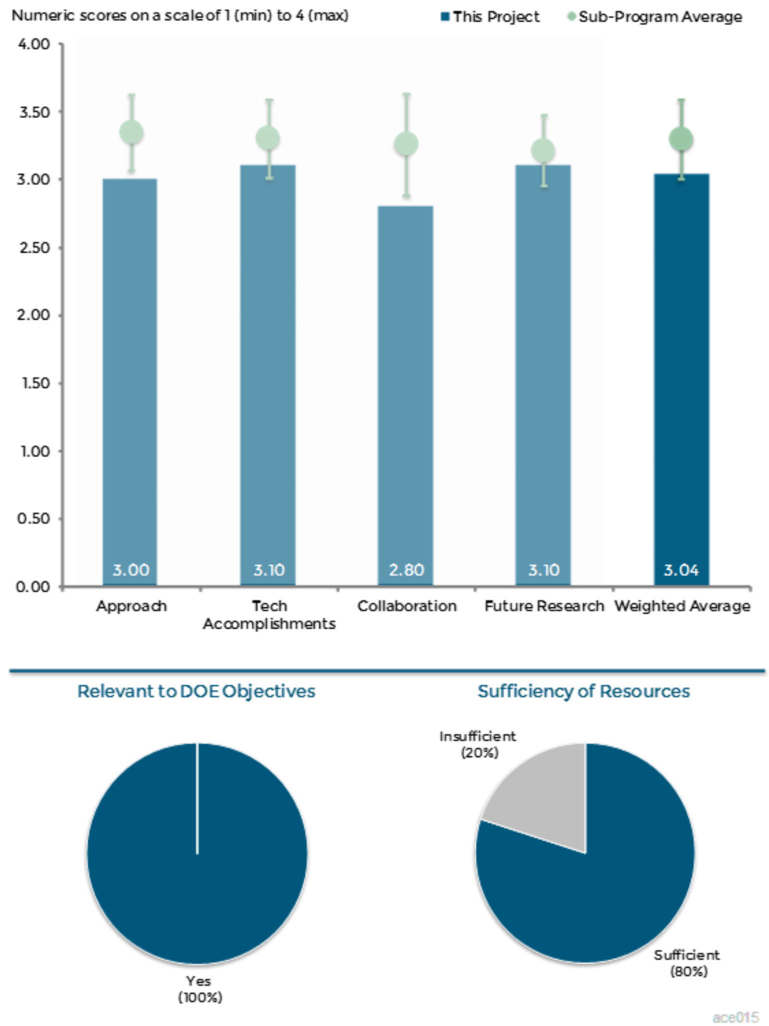

Figure 4-12 Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes: Stuart Daw (Oak Ridge National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer mentioned that the experimental efforts on the modified engine, and the associated reactor bench to understand fuel reforming required for this exhaust energy recuperation approach is very interesting. There are other similar projects, but this effort is certainly pursuing some good angles. This reviewer expressed looking forward to the catalytic EGR loop engine tests, if that would drastically improve reformates percentage to enhance combustion in the power producing cylinders.

Reviewer 2:

The reviewer commented that this is an innovative approach to waste heat recovery. This reviewer also pointed out that this work is a good pre-competitive type of research and even more so considering the modest budget of $300,000.

Reviewer 3:

The reviewer explained that this project broadly involves using thermodynamic analyses to identify strategies for improving engine efficiency, and experiments to test the viability of the concepts identified. The team has apparently been using thermodynamics analyses for this end for the past 10 years. The project is pursuing two approaches: reaching the requisite temperatures for reforming in a deactivated piston or employing a catalyst in an EGR system that could promote fuel reforming to produce a sufficient quantity of hydrogen (H_2). For in-cylinder reforming, presumably that piston would provide no contribution to the overall work output in the normal sense and, thus, to fuel economy. Interestingly, there is some evidence that EGR dilution can offset the efficiency penalty of cylinder deactivation. The reviewer suggested that his is unorthodox, and indicated in the most recent efforts the PIs are investigating strategies for utilizing the exhaust waste heat to offset system irreversibility by recovering work, and thereby leading to improved engine efficiency. The reviewer observed that the particular approach here is to utilize the excess exhaust heat to promote steam reforming of fuel as a source of H_2 to allow the dilution limit to be extended prior to combustion instability. The H_2 would come from a sort of sacrificial piston in an MCE or externally in an EGR with a suitable catalyst and partial oxidation. The reviewer commented the source of the water (H_2O) was unclear and asked if it comes from the complete combustion of the fuel and is there enough H_2O naturally present in the exhaust stream to meet the supply of H_2 required. The reviewer remarked that the PIs note that about 20% of system losses come from brake work and exhaust waste heat, while about 80% is associated with system irreversibility of friction, coolant and other sources. The reviewer asked that the team please provide some logic of why their focus is on the 20% and not the 80%. This reviewer concluded that it would seem that more is to be gained by working to reduce a large contribution than a small one.

Reviewer 4:

The reviewer explained that increasing engine brake thermal efficiency has always been a major and challenging task for combustion engine specialists. In this direction, reforming for combustion engines utilizes steam reforming technology for converting waste gases into a source of energy. The authors' research of reformate, dilute combustion through thermochemical recuperation (TCR) is an innovative approach, showing that on-board production of H_2 may decrease fuel consumption under certain conditions. Their two proposed parallel approaches (in-cylinder and EGR-loop reforming) are definitely appropriate within the DOE's research requirements of new, more efficient combustion regimes, but with a high-risk approach, given the H_2 direct utilization on the engine. The intention seems to be in the right direction but, because on-engine testing has not been developed or demonstrated yet, there are still many experimental barriers to overcome towards building an entire flexible engine platform. The lack of any analysis results would seem to indicate that this is primarily a hardware driven program. This reviewer indicated that as comments last year suggested, CFD would be a powerful tool to understand and improve the concept.

Reviewer 5:

The reviewer pointed out that 30% EGR engines has already been demonstrated. One of the unintended consequences of improving engine efficiency is that exhaust temperature is reduced, thus reducing the opportunity for waste heat recovery. EGR Loop Reforming looks a lot like Dedicated EGR from Southwest Research Institute. This reviewer agreed that the catalyst development in a lab environment is a great idea prior to engine testing. The reviewer asked why send exhaust back into a cylinder for fuel reforming. Nissan presented a paper at a Society of Automotive Engineers (SAE) Congress showing an EGR loop fuel reforming catalyst.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the technical accomplishments are excellent from the reactor bench tests and fundamental understanding of fuel reforming process. Aggressive insulation to increase in-cylinder reforming temperatures should have been addressed quickly, which seems like a shortcoming that can be easily addressed in an experimental setup. The efficiency improvement seems to be only slightly better than cylinder deactivation.

Reviewer 2:

The reviewer commented that the project team has produced an engine platform that is flexible enough to accommodate in-cylinder reforming evaluation and external EGR reforming. The project team identified a barrier to reforming, namely low apparent temperatures. This reviewer then pointed out that it was hard to follow how the various tasks contributed to the ultimate goal of demonstrating the viability of EGR or cylinder deactivation as viable approaches for steam reforming. Experiments to measure cylinder pressure and evaluate performance of a catalyst for EGR reforming were reported. The reviewer highlighted that in basic experiments to identify conditions required for reforming it was found that temperatures on the order of about 1000°K are required, while the thermal conditions for reforming in one cylinder apparently are not sufficient to reach that level (Slide 12). The project team is investigating the possibility to increase temperature by redesigning the exhaust manifold, but proposals for alternative manifold designs were not clearly presented and costs for the proposed designs not discussed.

Reviewer 3:

The reviewer indicated that the project team showed fuel consumption benefits along with improved reforming under lean operating conditions, meaning low and part loads, but questioned what happens at high loads. Having a modified, dedicated low-cylinder-number intake manifold will still be able to provide the high, required flow to sustain high loads. There are many reasons for which numerous engine manufacturers still consider on-board reforming as impractical. Perhaps the project team should explain or investigate what are the overall effects, for example improved fuel efficiency over loss of rated engine power. Also, Slide 15 shows one efficiency reformed-based point but the reviewer did not see a plot showing a trend of DOE's required stretched efficiencies using this reforming approach. The reviewer suggested that perhaps a plot showing more such points would help.

Reviewer 4:

The reviewer expressed an interest in what aftertreatment strategy would be expected to work with a lambda = 1.1 exhaust products.

Reviewer 5:

The reviewer asked if a favorable operating condition for reforming includes a lean condition, does that imply lean aftertreatment for a production, emissions compliant, implementation of this technology.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer indicated that the level of collaboration is excellent too. Comparative analysis with other similar projects approaches and results is always beneficial to ground the audience with regards to the baseline and advances and limitations of such novel approaches. This reviewer also suggested that a slide on that should be included in the next review.

Reviewer 2:

The reviewer agreed that there are good collaborations with academic experts in key areas, but additional collaborations needed with industry to help guide the project.

Reviewer 3:

The reviewer acknowledged that the project team, while accomplished, does not include an industrial stakeholder in the engine manufacturing community to give some credibility to the concept of steam reforming within the environment of a deactivated piston/cylinder in an MCE. This reviewer also warned that there could be some concern if industry would not accept marketing engines in which one of the cylinders was deactivated or essentially not used to produce power but rather to serve as an environment to promote steam reforming.

Reviewer 4:

The reviewer noted that the project team is leveraging knowledge and expertise at other laboratories and universities, but industrial collaboration appears to be lacking. Bringing in some additional resources to do CFD work would undoubtedly prove useful.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer explained that the future work plan seems mostly about continued testing, though with specific conditions not especially well defined, it seems broadly reasonable. Parametric investigations of in-cylinder reforming, which is vague, will be pursued. In addition, more work on catalytic EGR loop reforming will be pursued, albeit it is vague.

It was suggested that future work should include efforts to bring onto the team an engine manufacturer. If the PI cannot convince the engine industry that the approach is viable and the industry has little interest in pursuing the concept, the work would not be worth pursuing.

Reviewer 2:

The reviewer commented that of acute interest will be the transition from the bench flow reactor experiments to on-engine testing, to further study the operation, durability and performance of the rhodium (Rh)-based catalyst.

This reviewer also indicated that because a non-firing cylinder penalizes friction, the question arises if there will be an ultimate benefit of in-cylinder reforming.

Reviewer 3:

The reviewer appreciated that this project is looking at unconventional approaches. There is a need to continue to focus on how the interesting chemistry effects can be leveraged to improve engine efficiency.

Reviewer 4:

The reviewer indicated that the path forward looks good. External catalytic reforming should enhance the results. It is required to establish an H_2 concentration target for the engine to enhance combustion and heat release. Another reviewer questioned if that can be quantified. The reviewer questioned if an application to heavy duty is possible also.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer pointed out that increasing engine efficiency will reduce petroleum usage.

Reviewer 2:

The reviewer explained that this is certainly a revolutionary approach to exhaust heat recuperation to enhance combustion with fuel reforming in a partially deactivated engine at low brake mean effective pressure (BMEP).

Reviewer 3:

The reviewer stated that the project is broadly relevant to the goal of improving fuel economy. It is unclear, though, how the approach fits in with the 35% target. This reviewer also indicated that the idea of in-cylinder reforming is risky and unorthodox, hence the recommendation to bring on an engine manufacturer.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that experimental efforts for this engine research can use more funding.

Reviewer 2:

The reviewer agreed that the annual project costs of about $300,000 seem reasonable.

Reviewer 3:

The reviewer indicated that some reallocation to include more analysis to speed development and seeking industrial participation to ensure the technology has someplace to go in terms of application is highly recommended.

High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Engines: Scott Curran (Oak Ridge National Laboratory) - ace016

Presenter

Scott Curran, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of six reviewers evaluated this project.

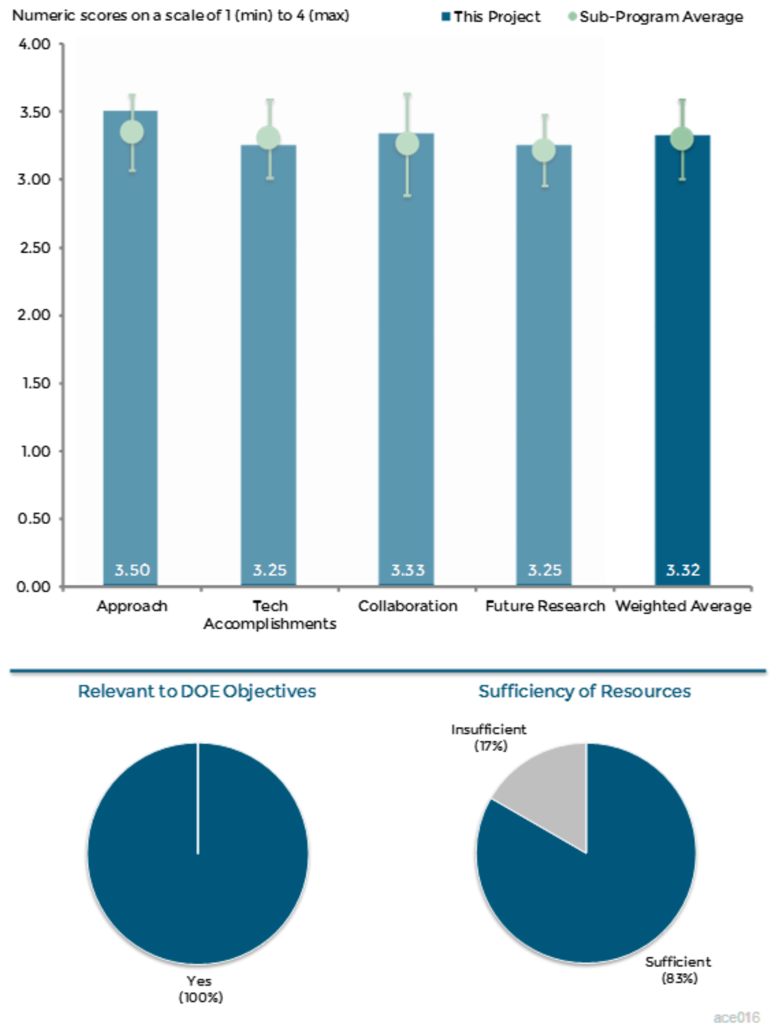

Figure 4-13 High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Engines: Scott Curran (Oak Ridge National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that the systems level approach of evaluating advanced combustion technologies through testing on a multi-cylinder production engine platform with realistic auxiliary equipment coupled with drive cycle simulations is an excellent approach for assessing the real benefits and challenges of these technologies. The approach also helps to refine the results obtained from single cylinder studies.

Reviewer 2:

The reviewer commented that it was very nice to see a practical engineering evaluation of a reactivity controlled compression ignition (RCCI) powerplant in a vehicle. The approach has been outstanding throughout the years toward integrating research level activities in high efficient combustion strategies to multi-cylinder engines and then eventually into a LD vehicle.

Reviewer 3:

The reviewer stated that the approach is very good. A multi-cylinder systems level approach, with real air-handling systems, etc. is followed, which is needed to understand the real potential of LTC systems

Reviewer 4:

The reviewer observed that the project approach of looking at combustion through vehicle level efficiency is appropriate for evaluating the potential for LTC modes to replace diesel combustion. This reviewer expressed will be happy to see results using the new noise and vehicle fuel economy metrics as those will be much more indicative of how the engine might run in real-world use. As many of the reviewer questions hit on, the real key will be how to handle cold-start, warmup, and transient operation. It seems safe to assume that aftertreatment will always be required so consideration of the engine in light of that reality seems important.

Reviewer 5:

The reviewer expressed an agreement that the project is valuable in taking a concept such as RCCI towards its validation on a production platform. The project emphasizes the importance to work on the system integration and the respective challenges.

The project would benefit by including a technology review of previous RCCI that will frame the expectation of both load extensions, fuel consumption and emissions benefits.

Reviewer 6:

The reviewer said that application of RCCI/LTC, and addressing lack of emission data.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer reported that excellent progress in evaluating the RCCI technology, including: development of RCCI engine maps for using the drive cycle simulations; demonstration of capability to obtain an efficiency in an MCE that meets the 2020 ACEC stretch goal of 36%; and evaluation of the performance and emissions of UW's hybrid RCCI vehicle.

Reviewer 2:

The reviewer indicated that the technical accomplishments have been outstanding especially in assessing the possibility of using RCCI in powerplant. Though the results have been limited to predominately steady-state conditions the accomplishments have nevertheless been impressive. This reviewer also suggested that future work should further address key challenges with this type of engine system.

Reviewer 3:

The reviewer observed that good progress has been made. Work towards evaluating transient control capabilities of RCCI should be accelerated.

Reviewer 4:

The reviewer agreed that the work in the last year has moved things forward, with evaluations of the drive cycle potential (absent emissions), and other features of RCCI. This reviewer expressed a need to see more discussion of the likely fuel economy penalty between a laboratory demonstration and a production calibration level engine so that the comparisons to production baselines are more realistic.

Reviewer 5:

The reviewer commented that the project team completed engine maps covering RCCI over a wide portion of the map. Fuel efficiency improvements, which are applicable to a portion of the drive cycle, give estimates of the fuel economy gains within the targets of the program. This was applied to wide range of engines across two cycles. The project includes good instrumentation, especially in the PM sample and size distribution, via TSI and tandem differential mobility analyzer. The work provides a valuable insight to adapt RCCI to a hybrid powertrain. This was shown to be useful too in the EPA-led HCCI studies on medium duty (MD) engines on an UPS demonstration. This reviewer recommended that the project team provide heat release traces and an energy breakdown that are tied into the reported operating efficiencies. The figures of Slide 10 are informative but require more explanation. The reviewer explained that the engine has two fuel injectors, retaining the diesel DI unit. Results report UHC, CO, NO_x. No data is given of soot. This reviewer suggested that it may be valuable to understand the soot-NO_x tradeoff and what optimization has been done or is planned, as for example, the diesel injector nozzle hole geometry and pressure sensitivity as this fuel will be responsible for most of the soot emissions. The reviewer stated that engine out NO_x seems high and questions if it is likely that lean NO_x aftertreatment will be needed after all. The reviewer warned that engine-out HC is high and combined with low exhaust temperature that poses a problem. Extensive warm up with diesel only might erode into efficiency gains with LTC. This reviewer declared that it is commendable that the ACEC noise and efficiency recommendations are being followed.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer confirmed that the PI has done a great job leveraging many resources throughout the years. Great job!

Reviewer 2:

The reviewer noted that the growing collaboration with LANL and SNL will be very good. The existing collaborations seem effective, though the reviewer would argue that ORNL has gone well past UW in terms of useful RCCI work.

Reviewer 3:

The reviewer indicated that a good level of collaboration with one auto manufacturer and two equipment and catalyst suppliers as well as several universities and the other national laboratories.

Reviewer 4:

The reviewer said that it is a good team. Very impressive to see how the project incorporated the UW at Madison hybrid vehicle and National Instruments controller.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer agreed that the plans going forward do appear well positioned to pick off the main trouble points for RCCI. This reviewer would encourage as much effort towards transient operation and dealing with the mode switching and emissions variation from that style of operation as being key. The series hybrid results were interesting, but not realistic for what vehicles will operate like.

Reviewer 2:

The reviewer stated that that planned work to look at multi-mode transitions and the needs of auxiliary equipment and aftertreatment will help to further evaluate the viability and needs of the RCCI technology.

Reviewer 3:

The reviewer pointed out that the team highlighted remaining challenges and barriers, including load extension, transients and controls, and aftertreatment.

Reviewer 4:

The reviewer indicated that the proposed work is very reasonable. The only suggestion is to include some focus on the warm strategy for the RCCI powerplant and also work hard to refine transient control on the MCE RCCI engine.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer stated that the project directly supports DOE goals by evaluating one possible multi-cylinder high-efficiency low-emission engine system.

Reviewer 2:

The reviewer noted that the assessment and comparison of various advanced combustion technologies on the same MCE platform is very valuable for identifying the technology or technologies that have the most promise for improving engine efficiency and reducing emissions to best meet or exceed DOE goals.

Reviewer 3:

The reviewer reported that this project is well aligned with enabling production consideration of LTC.

Reviewer 4:

The reviewer explained that it is important to have a program where the initial concept of RCCI done mostly at the university level can be evaluated more thoroughly and the barriers and challenges be more clearly identified by a team such as the one consolidated at ORNL.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer brought to light that the downward trend in funding for this project is troubling. The work done here is perhaps the most focused on real-world issues with LTC and should receive funding in proportion to that.

Accelerating Predictive Simulation of Internal Combustion Engines with High Performance Computing: Kevin Edwards (Oak Ridge National Laboratory) - ace017

Presenter

Kevin Edwards, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of seven reviewers evaluated this project.

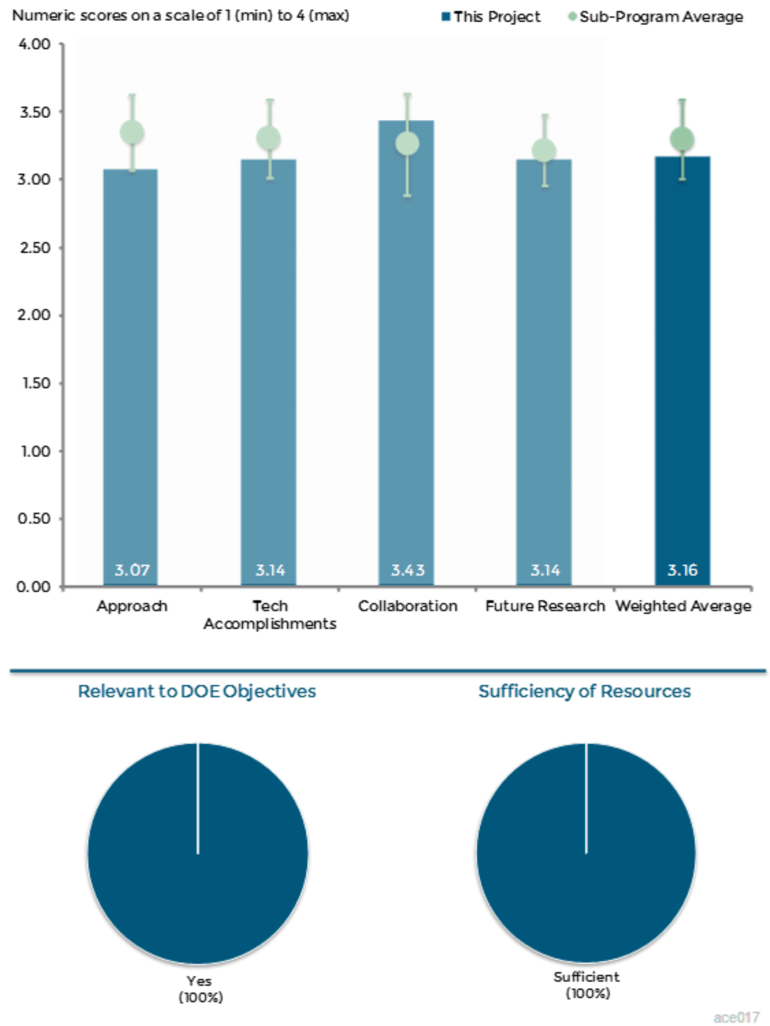

Figure 4-14 Accelerating Predictive Simulation of Internal Combustion Engines with High Performance Computing: Kevin Edwards (Oak Ridge National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that there is no doubt that multidimensional engine analysis is key to understanding what's going on inside the cylinder of an IC engine (particularly when coupled with optical and conventional engine experiments). As more challenging efficiency and emissions requirements emerge, the need for more and better engine simulations grows, thus the requirement to accelerate the analysis process with high performance computing. The reviewer concluded this project does an exceptional job of marrying the facilities at the national laboratory level with the engine makers who can make the most use of these resources to advance engine technology.

Reviewer 2:

The reviewer explained that this project concerns developing a predictive capability for an ICE. The rationales that motivate the effort are common among projects that are simulation-based, for example facilitate design, reduce time-to-market, and reduce cost. The approach taken is to combine two codes, openfoam and converge, to validate, improve, and employ predictive injector flow models with the ultimate purpose to solve the unsolvable. This reviewer suggested that it would help the project if some discussion could be devoted to the limitations of existing simulation tools that motivate the one(s) employed here: some context would be useful. The reviewer commented that some codes are free with full access to the source code while others are not. As presented, there was little discussion of why Converge was chosen (for example) beyond that it is a good spray solver, that it can predict cavitation or flash boiling during the injection process, or that it is what the industrial collaborators want to use. The reviewer questions what about the use of KIVA (LANL), RAPTOR (SNL) and others. The PI brings unique expertise, computational capabilities and their extensive knowledge to the project and should advise the industrial collaborators rather than (if this is the case) just use what is wanted. It was suggested future presentations should list the virtues and limitations of competing computational tools. Nothing is perfect and the community would benefit from the PI's perspectives. The reviewer noted that the ultimate goal of a fully predictive simulation approach is to improve engine efficiency. However, it was difficult in this presentation to see the link of all the tools being developed to this end. For example, the reviewer expressed a need to understand if spray penetration can be accurately predicted, how this will be quantitatively related to fuel economy, if droplet collisions occur, and what the impact is of the physics on efficiency beyond qualitative connections.

Reviewer 3:

The reviewer stated that the project seeks to use high speed computing to improve the predictive capabilities of simulations. The simulation times reported are long and costly. The reviewer suggested that the authors need to show how to bridge the use of these massive computational tools to practical industrial applications, beyond the selective demonstration projects that are selected here (e.g. the General Electric [GE] locomotive project).

Reviewer 4:

The reviewer acknowledged that implementation of industry relevant CFD software to super computers is a great step. This reviewer questioned how this capability can be rolled out to additional industrial partners.

Reviewer 5:

The reviewer reported that HPC coupled with an industry partner helps to ensure relevance of project results.

Reviewer 6:

The reviewer affirmed that the approach to develop and improve the understanding of fuel injector behavior is important to improving combustion efficiency and bringing technologies to market with reduced development time and cost. This reviewer also noted that it is unclear the level of involvement from suppliers or OEMs in the definition of the approach. If the intention is to improve understanding of the fuel injection systems, the reviewer questioned if new nozzle geometries, nozzle hole manufacturing processes, coatings and other key relevant aspects of the fuel injector have been considered in a matrix to actually perform the optimization. This reviewer also asked if the goal of this study is only the development of the tool and not the use of the tool itself to effect change by component or system level optimization. The reviewer said that there is a goal mentioned to translate the capabilities from HPC to desktop on board diagnostic (OBD) and controls, but did not see a path to achieve this technical goal. It is unclear if an OEM could use this tool in a practical manner without HPC. The reviewer asked what the path is to removing the need for powerful computations for the aforementioned tasks. The reviewer indicated that the studies on cyclic variability are interesting and important for future combustion control regimes, but it is unclear if this is part of ace017 or ace090. The study on GPU acceleration of numeric solvers approach is in its infant stages. The reviewer commented that it is stated that in Fiscal Year 2017-2018 a demonstration of an accelerated, fully optimized injector design will be done, and asked if this project ace017 will continue for three more years to accomplish this goal. There is no communicated percent complete to date information or information about the future project timeline communicated in a clear manner. The reviewer explained that it is difficult to assess the approach for the remainder of the project or what is inside or outside the scope of ace017 because the presentation is inclusive of information pertaining to multiple projects at multiple phases. This reviewer expressed that one cannot asses with confidence what is really being done in ace017 and cannot therefore give a clear assessment of the approach.

Reviewer 7:

The reviewer expressed that one is not sure if HPC has a pathway to being used as a design tool by industry. It takes too long and it costs too much. It is certainly a long-term play.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that progress on the various projects has been excellent. Of course, there are many more challenging problems out there (it is a target rich environment), so the team is encouraged to continue seeking out new partners and new problems to tackle. The Cooperative Research and Development Agreement (CRADA) bringing together ORNL, LLNL, Indiana University, and Cummins is a positive step in this direction - more joint work with other laboratories (ANL comes to mind) as well as more industrial and academic partners is encouraged.

Reviewer 2:

The reviewer indicated that the GM fuel injector simulation results are looking good. It seems like the model is able to predict flash boiling quite well. This reviewer expressed that one is not sure what kind of progress is being made on the Ford cycle-to-cycle variability. Perhaps the goal and progress on this project needs to be described better so the reviewer can understand it better. The reviewer noted an agreement that the GE Diesel Locomotive Natural Gas project is very relevant and interesting.

Reviewer 3:

The reviewer explained that simulations and developments to date seem to be progressing, with test data and simulation data being generated as planned. In order to accomplish the task of reducing time to market for technologies and improving fuel economy. It would be helpful to see how this tool is expected to reduce time to market or improve efficiency in reality. The start to finish injector design that is planned will be vital to understand the success of the program, and to see if it could be done faster and with less cost than traditional simulation and test methods. The reviewer stated that there is a goal mentioned to translate the capabilities form HPC to desktop to OBD and controls, but the reviewer did not see a path to achieve this technical goal. It is unclear if an OEM could use this tool in a practical manner without HPC. This reviewer also questioned what the path is to removing the need for powerful computations for the aforementioned tasks.

Reviewer 4:

The reviewer noted that the authors have selected a GDI fuel injector for design optimization. The present effort appears focused on approach and methodology. The work is coordinated with GM facilities. Work currently focuses on internal flow nozzle description and the impact of flash boiling on plume angle (modeling). Tests included a range of ambient temperatures highlighting the effects in the injection pattern. Work will then continue by incorporating models on Converge for engine modeling studies. This reviewer suggested that the overall direction of the project may be better appreciated if the authors provide a detailed list of issues or concerns and their prioritization. The reviewer mentioned that the project also looks at cycle-to-cycle variability including impact of stochastic input noise on the simulations. The authors highlight the high sensitivity of the noise in highly dilution cases. The reviewer also expressed that it is unclear how effective or practical the uncertainty quantification meta-model approach. The reviewer explained that the variability analysis was applied to a locomotive dual-fuel engine but there is little representative data. No discussion is given to possible mechanisms to limit variability; nor is variability depicted as a function of key parameters such as dilution, combustion timing, diesel-to-natural gas ratio, etc.. As noted earlier, it is unclear what value this brings. The reviewer observed the CRADA for GPU acceleration of numeric solvers appears to be beginning. This reviewer also stated that regarding the cyclic variability, the tool is being developed and first analysis indicates experimental data is matching simulation results in a sufficient manner.

Reviewer 5:

The reviewer suggested that regarding injector spray design optimization, a description of the optimization criteria for the injector design would help the audience understand the task and the trade-offs involved.

Reviewer 6:

The reviewer questioned if correlation between simulation and hardware for injector sprays be quantified. Visual spray comparisons appear to correlate but a quantifiable metric would be good.

Reviewer 7:

The reviewer explained that this was a difficult project to evaluate because the organization of the topics was not especially clear, making it more difficult to follow the progression of thought in several spots, and suggested that in presenting the technical accomplishments, it is recommended that the PI list, perhaps restricted to just one slide, the things done then pick one or two to discuss in greater detail. The model validation seems to involve comparing spray imaging with (apparently) predicted spray patterns (it was not very clear how the validation was carried out, though) using results from GM's visual interference imaging set up and cylinder pressure at various crank angles. This reviewer also stated that the confusion here is that it was thought that the reporting year did not consider combustion. The reviewer asked if the data in this validation were taken under combusting conditions. The spray images seem qualitative. The reviewer questioned precisely what data comes from them, what their uncertainties are, what is being predicted, and what is being measured. The reviewer asked if things like measured spray penetration or cone angle are being compared, is that enough to assess the efficacy of numerical tools. The reviewer also asked what about SMD and the distribution of velocities. These items would provide a more stringent test of the code's capabilities, even for the case of injection into a cold ambience. The reviewer suggested that more quantitative variables for validation should be used than simply what appear to be fuzzy images of sprays penetrating into a combustion zone, if that is what was done. The reviewer stated that if hexane is being injected into a 40 atm ambience, it would seem that dissolved gas effects could influence the results and asked if that is that correct. The reviewer questioned why the collision and coalescence model of converge turned off and why not turn it on. The reviewer observed that the PI notes that droplets were injected in the post-primary atomization process. This reviewer also suggested that more simulations on droplet trajectories and sizes would be useful, especially for cases where the droplets are in the process of evaporating. The reviewer noted that flash boiling was mentioned. It is not clear precisely what fuel was examined. Because vaporization under such conditions requires some degree of super-cooling, discussion of this point should be provided. The reviewer asked if the PI knows the conditions under which the fluid thermal state must vaporize in a flash boiling configuration and if not can the PI measure it.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer indicated that there is a wide range of collaborators across national laboratories, academia and industry, which supports various projects within the program run at ORNL. Teams appear well integrated. Nevertheless, the collaboration effort needs to be demonstrated in establishing successful industrial demonstration projects.

Reviewer 2:

The reviewer remarked that the collaborative efforts with partners is impressive and broad. It would be beneficial to see more involvement from an injector suppler to help define a simulation and test matrix for injector optimization in a targeted combustion system to support the stated desire to perform design iterations for a real world optimization.

Reviewer 3:

The reviewer commented that there are many team members and a lot of tasks are being pursued. The collaborations seem reasonable, but the presentation was not especially clear (beyond mere statements) what certain entities were doing that contributed to the project. This reviewer also suggested that for a complex team greater thought should be given to how the pieces fit together. Perhaps a reduction in the scope of this project would help to bring greater focus to it.

Reviewer 4:
The reviewer reported that the partners in the projects to date seem well integrated and making good use of the resources that ORNL has to offer.

Reviewer 5:
The reviewer pointed out that it was good to see collaboration with CSI and LLNL to implement GPU-based Converge. This will eventually impact the speed with which industry can run simulations.

Reviewer 6:
The reviewer said that there is good collaboration with GM and Ford.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer acknowledged that the planned future work is vital to the success of the project. To not only develop the tool but to make it available for use with OpenFOAM, CONVERGE is very good. This reviewer explained that the goal to perform an injector design is very interesting if the simulation and test matrix is planned out in a manner such as design of experiments which is broad enough to truly optimize an injector, not just the testing of one injector to validate a model. The reviewer observed that the cyclic variability to comprehend and understand the key contributors to variability will be interesting.

Reviewer 2:
The reviewer explained that GPU technology may be a game changer, making large scale engine simulations cheaper and faster with the right software. Unfortunately, the traditional CFD software grew up on the CPU and some significant rethinking of how memory is used may be needed, but remarked that it will be interesting to see if the LLNL/ORNL/CSI team can make this jump. If possible, the results could make large scale simulations with detailed chemistry more than just an academic exercise and an even more powerful design tool.

Reviewer 3:
The reviewer pointed that out the future work is outlined briefly. This includes validation of injector model, apply meta-model approach to support experimental high-dilution control efforts at ORNL, identify and refine additional stochastic parameters and deterministic feedbacks for dual-fuel combustion, and implement GPU acceleration for flow and combustion solvers. This reviewer also suggested that the work appears to need a more visible tie-in to concrete milestones.

Reviewer 4:
The reviewer summarized that that the remainder of 2015 is to evaluate impact of LES turbulence on combustion stability. The reviewer commented this is nonspecific. In fact, this reviewer expressed the thought that combustion conditions were already part of the reporting year and that this issue (of turbulence) would be folded into the simulations that compare cylinder pressure with crank angle. It is a bit confusing. The reviewer said that real-world engines are noted and would like to know if the PI can be more specific. The reviewer suggested that more discussion of the flash vaporization process should be provided. This is a well-known process and it would be useful to know what is new about what the PIs' are doing in this area.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that a computational predictive capability of an ICE is, of course, important for improving engine efficiency.

Reviewer 2:

The reviewer mentioned that model predictability is an important element of combustion development.

Reviewer 3:

The reviewer reported that more efficient engines result from better designs. Multi-dimensional engine modeling can be shown to lead to better designs (ask the industry collaborators on this project). High performance computing facilitates better and faster simulations, better enabling, and more efficient designs that may not displace petroleum, but certainly reduce its consumption.

Reviewer 4:

The reviewer indicated that if combustion efficiency can be improved by finding an optimal combustions system, petroleum consumption could be reduced.

Reviewer 5:

The reviewer stated that the project supports the long term goal of HPC helping in the design of practical engines. However, it is not clear if industry is on a pathway to HPC currently.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the influx of CRADA money is hopefully the beginning of a trend to more industry support of this effort.

Reviewer 2:

The reviewer noted that this is a rather large team. Most of the computational effort seems to be at ORNL. It would help if the PI could give a breakdown of how the $400,000 was spent, because this category presumes the availability of such information (for example, resource sufficiency cannot easily be evaluated without knowing what the resources are used for)

Reviewer 3:

The reviewer commented that more clarity is needed in terms of the relative contributions of funding sources and the specific scope elements that they are fulfilling.

Joint Development and Coordination of Emissions Control Data and Models (CLEERS Analysis and Coordination): Stuart Daw (Oak Ridge National Laboratory) - ace022

Presenter

James Pihl, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of four reviewers evaluated this project.

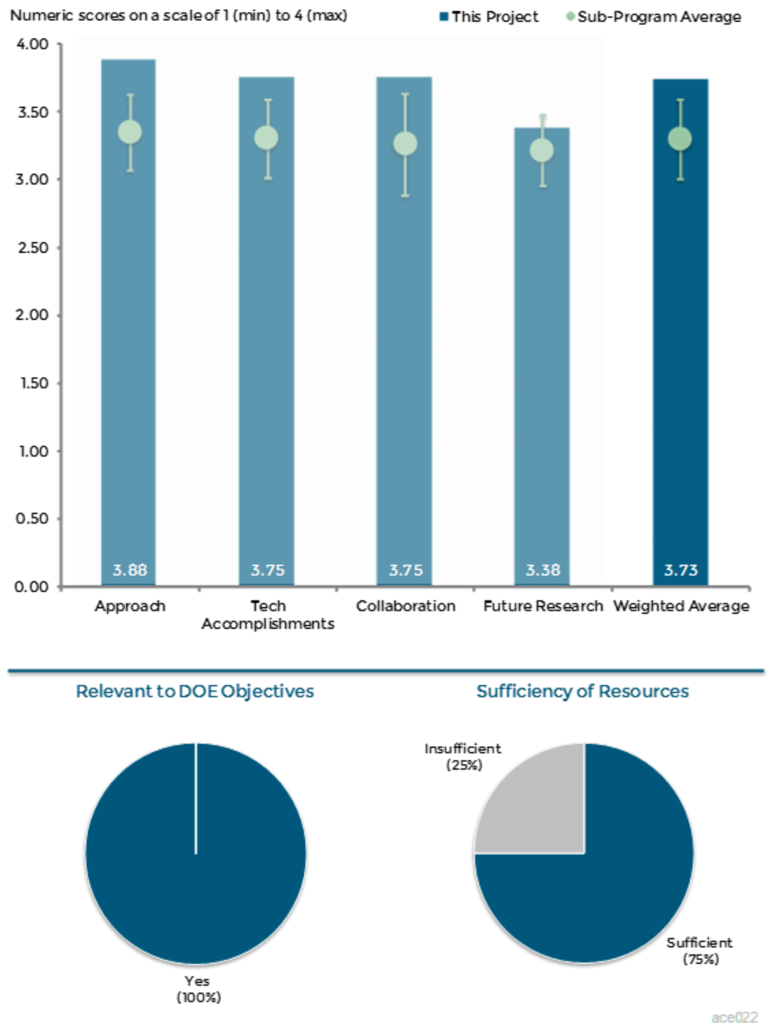

Figure 4-15 Joint Development and Coordination of Emissions Control Data and Models (CLEERS Analysis and Coordination): Stuart Daw (Oak Ridge National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that this an outstanding effort. Cross-cut lean exhaust emission reduction simulation (CLEERS) has many moving parts and the approach continues to improve continuously year on year. Seeking input from industry customers is key and well-designed through workshops and regular meetings. This reviewer clearly observed topical R&D with selective catalytic reduction (SCR), diesel oxidation catalyst (DOC), PM, low-temperature catalysts, and other systems modeling on target list.

Reviewer 2:

The reviewer stated that the approach used in this work to understand the utilization of ammonia (NH_3) in an SCR is of great interest to the OEMs and lean aftertreatment community in general. The information obtained in this project has additional implications for OBD groups that are charged with developing routines to characterize the health of emerging aftertreatment technologies such as SCR catalysts.

Reviewer 3:

The reviewer noted that this approach of supporting models that are used for improved fuel economy and emission’s control is working very well. The CLEERS approach also leads to excellent communication within the practitioner community, communication that did not exist several years ago.

Reviewer 4:

The reviewer acknowledged that CLEERS workshops are always a great way for the emissions community to come together and share pre-competitive information. The monthly audios are also very effective for maintaining good communication and promoting collaboration within the emissions community.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer explained that the project plan, technical approach, and tools used in this work are very appropriate and provided a significant amount of useful information. Developing models to predict the NH_3 storage capacity of SCR catalysts and the storage sites is critical to understanding how to react NO_x under lean conditions and regenerate the catalyst with NH_3 for optimal NO_x reduction activity with minimum use of reductant species. This reviewer also commented that this type of research effort, which is also supported by CLEERS, is best provided by a national laboratory. The reviewer commented nice work.

Reviewer 2:

The reviewer indicated that the many goals for the CLEERS project were all completed. Being able to use component models in architecture studies for areas that were not intended to be used is impressive, for example, hybrids. The reviewer stated that NH_3 isotherm work in the presence of water is impressive and leads to a model that is very effective. Also, this reviewer said that there is good understanding of means of N_2O formation in lean NO_x traps (LNTs).

Reviewer 3:

The reviewer reported that CLEERS continues to stay focused well through workshops and teleconferences and has contributed to important advances in R&D for SCR, LNT regeneration, and SCR. To rate the project outstanding, CLEERS can support breakthrough R&D in passive SCR and LTC efforts.

Reviewer 4:

The reviewer remarked that the workshop and the audios are always very effective and well-run, and the efforts of those involved in organizing them are greatly appreciated, but suggested that DOE might consider extending the time for the talks to 25 minutes next year, in order to allow time for the presentation and also entertain questions. The reviewer indicated that good analysis was performed on the NH_3 storage capacity, especially the effects of H_2O and thermal aging, and particularly liked the investigation into the effects of the catalyst pretreatment on the NH_3 storage capacity. At this point, it looks like the 2-site model only allows another degree of freedom for matching the model with the data. The reviewer suggested that some investigation into the physical characteristics that determine whether a NH_3 storage site is a high energy site or a low energy site. The reviewer would like to see some other emission topics researched and modeled in addition to the NH_3 storage capacity of SCR catalysts and the N_2O formation from LNTs. One suggestion would be a greater emphasis on low temperature catalysis at stoichiometry.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer commented that CLEERS provides many excellent opportunities for communication and collaboration between national laboratories, industrial partners, and educational institutions around the world.

Reviewer 2:

The reviewer stated that CLEERS in 2015 is well defined and per its mission serves well the auto industry OEMs/Tier 1 Suppliers as well as parallel research at universities and national laboratories.

Reviewer 3:

The reviewer indicated that collaboration and support for many activities is extremely broad, especially for CLEERS workshop and CLEERS conference calls.

Reviewer 4:

The reviewer noted that collaboration and support for many activities is extremely broad, especially for CLEERS workshops and conference calls.

Reviewer 5:

The reviewer suggested that inclusion of an OEM or wash-coat supplier as a reality check on the approach and work would have benefited this project. Feedback from OBD groups would also help both the researchers and the end users better understand the conditions and strategies the technology can be best utilized.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer emphasized that this is an excellent approach to future R&D targets and industry needs are well based on funding. This reviewer also pointed out that HC traps and other aftertreatment approaches for LTC are key needs for R&D.

Reviewer 2:

The reviewer agrees that future work to address remaining questions and fill the knowledge gaps is appropriate.

Reviewer 3:

The reviewer stated that the move to passive NO_x adsorbers is very welcome. This reviewer expressed a need to only encourage that CLEERS at ORNL keep track of the issues that come along with the effort in low-temperature catalysis and with low-temperature exhausts that are cool even after the engine has finished its cold start.

Reviewer 4:

The reviewer noted that there appears to be emphasis on HC traps in the future work, and work on NO_x traps is delayed until the middle of fiscal year 2017, but would like to see a concurrent investigation into HC traps and NO_x traps, as both will be important for achieving strict emission standards.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer explained that the improved communication and collaboration between national laboratories, car manufacturers, and universities that CLEERS promotes can and will contribute to the development of more efficient powertrains and aftertreatment systems that will lead to improved fuel economy and reduced emissions on vehicles and thus a reduction in the national petroleum usage.

Reviewer 2:

The reviewer indicated that the modeling capabilities resulting from the experimental-modeling synergies within the CLEERS project are directly useful in developing pathways to using less fuel in emissions control.

Reviewer 3:

The reviewer specified that effective aftertreatment for new combustion strategies is critical for productive use of new petroleum saving combustion schemes. This reviewer also commented that low-temperature combustion and improved approaches for lean NO_x management are examples of focus areas in aftertreatment that are clearly needed to implement demonstrated combustion fuel efficiency improvement strategies.

Reviewer 4:

The reviewer pointed out that this project supports U.S. Council for Automotive Research (USCAR)/U.S. Driving Research and Innovation for Vehicle Efficiency and Energy sustainability (U.S. DRIVE) initiatives to address the need for effective lean aftertreatment systems and technologies. This type of characterization and modeling is useful for OEMs in the development of their aftertreatment strategies.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer suggested that it is possible to increase the scope of the project with incremental budget. It was indicated current funds are well managed and productive. There should be consideration of increasing funding to improve water line on R&D focus.

Reviewer 2:

The reviewer thought that the resources could be expanded at ORNL to allow concurrent development of HC traps and NO_x traps.

Reviewer 3:

The reviewer acknowledged that this project is appropriately funded and staffed.

CLEERS: Aftertreatment Modeling and Analysis: Chuck Peden (Pacific Northwest National Laboratory) - ace023

Presenter

Yong Wang, Pacific Northwest National Laboratory.

Reviewer Sample Size

A total of two reviewers evaluated this project.

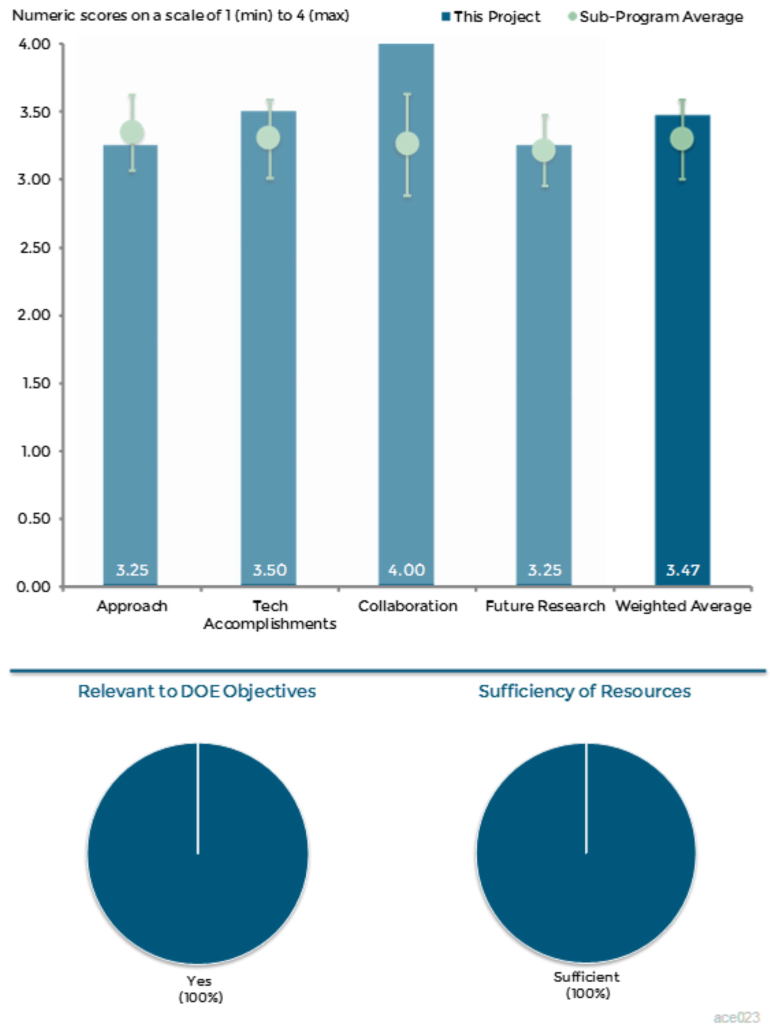

Figure 4-16 CLEERS: Aftertreatment Modeling and Analysis: Chuck Peden (Pacific Northwest National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work–the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the approach of having industry/others define needs, and then starting with fundamentals to satisfy these needs. These feed into CRADAs for beginning steps to practicality. Established and working. The reviewer concluded frequent communications to keep participants and industry informed and to solicit feedback.

Reviewer 2:

The reviewer expressed a warned concern about the overweighting focus on preparation methods for SCR as their relevance to modeling activities is not clear. It will be beneficial to measure and analyze the reaction kinetics and mechanistic pathways to show that the prepared model catalysts are relevant to practical applications. This reviewer also stated that it will also be helpful to understand better the aging and sulfur poisoning mechanism to facilitate aging model development.

The reviewer indicated that for passive NO_x adsorber (PNA), the focus should be on understanding the reaction mechanism and kinetics of NO_x storage/release, not on developing new catalyst formulations.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals–the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer pointed out that there was good quality work on SCR material preparation and characterization, and the mechanistic study on N_2O formation is of critical importance for SCR model development.

Reviewer 2:

The reviewer said that SCR and the explanation on N_2O preferential formation is very important. This reviewer also noted an expectation of a N_2O versus de-NO_x inverse relationship, and the need to quantify and inhibit. Synthesis accomplishments are important to provide model catalysts. This reviewer expressed a confusion on the significance for practical application although, it can provide a pathway to commercialization. However, the reviewer guessed that industry can develop their own methods. Finally, the reviewer the project is important for other researchers in their studies. The reviewer noted that very important and interesting results on the effect of iron (Fe) loading and Cu/structure relationships on SCR performance. Low-temperature aftertreatment protocol development is critically important. The reviewer questioned if others are beginning to use it. The reviewer stated X-ray/CT analyses of selective catalyst reduction on filters (SCRF) are interesting for assessing loading. This reviewer questioned to know what is next. The reviewer noted that the tool was developed and ready to apply. The reviewer was anxious to see application and impact on passive soot oxidation, diesel particulate filter (DPF) porosity impacts, and coating method, etc. The reviewer indicated that elements of the scope on GDI particulates seems to be similar to work at ANL with somewhat different results. The reviewer would like to understand the similarities in the these efforts and whether or not the corresponding results are consistent.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer explained that the CLEERS program is designed for collaboration, so an excellent score is inevitable. However, visiting scientists are the best collaboration and these are excellent for strong mutual benefit and dissemination of knowledge. The reviewer suggested doing more of this.

Reviewer 2:

The reviewer noted that close collaboration with industry (Johnson Matthey (JM) and Cummins).

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer explained that that with nitric oxide (NO) to nitrogen dioxide (NO_2) dependencies, much of the difference between copper (Cu) and Fe may be due to the cation itself and not the location or structure, but suggested starting experiments with this hypothesis rather than to go through many reiterations on structure. Also, this is a very important property. Design the studies with new ion candidates in mind especially those that would not be sensitive to sulfur. The reviewer pointed out that durability work versus structure is important, but just as critical is sulfur tolerance. There is no work on poisoning for any new promising structures. The reviewer indicated that NO_x storage reduction (NSR) is becoming important for LD (as always) but also for California Air Resources Board (CARB) low-NO_x cold start regulations. Aging and sulfur tolerance become more critical in heavy duty (HD). The reviewer noted that on SCRF, the biggest issue emerging is impact on passive soot oxidation. This reviewer also explained that the project is gaining knowledge on zeolite structure, NO to NO_2 oxidation, and on x-ray CT and indicated the project is well-poised to expand earlier work on passive soot oxidation inhibition with SCRF.

Reviewer 2:

The reviewer suggested that the focus of this activity should be on generating knowledge on the reaction kinetics and mechanism to feed the modeling activities, not on developing new catalyst preparation methods.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

This reviewer indicated that emissions regulations are tightening again and suggested low-FC strategies have unique problems and need emissions help.

Reviewer 2:

The reviewer said that SCR is a key enabling technology for diesel and lean burn gasoline engines.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that the results are impressive given the resource allocation. Unless there are changes, the progress should continue.

Particulate Emissions Control by Advanced Filtration Systems for GDI Engines: Hee Je Seong (Argonne National Laboratory) - ace024

Presenter

Hee Je Seong, Argonne National Laboratory.

Reviewer Sample Size

A total of two reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

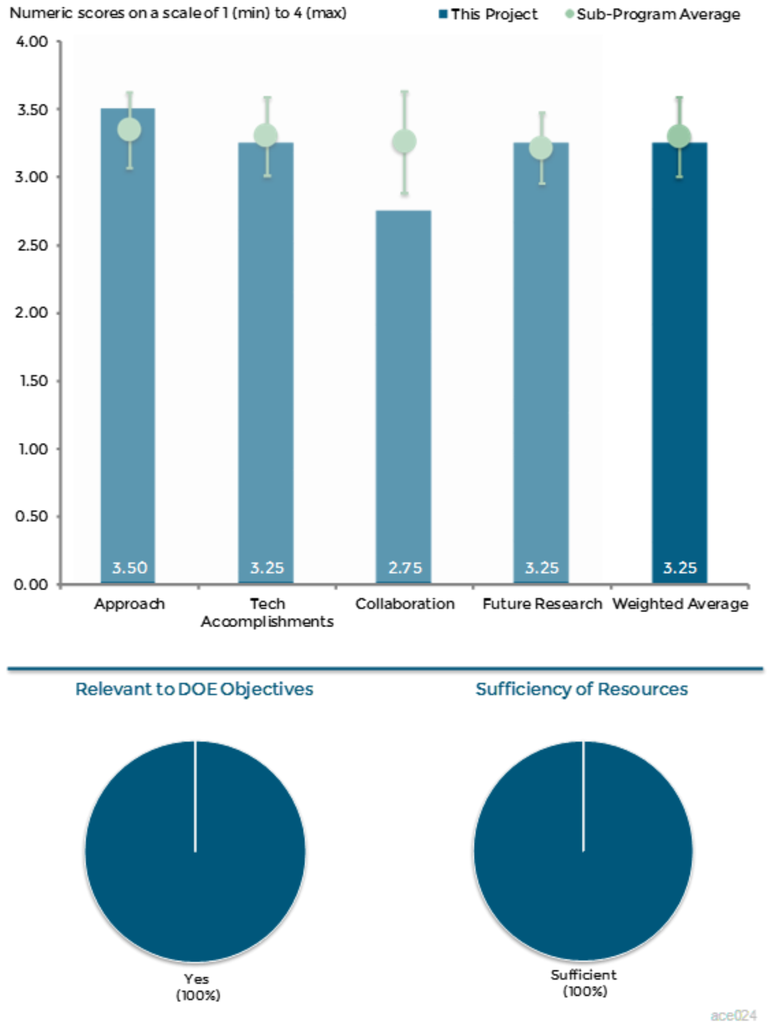

Figure 4-17 Particulate Emissions Control by Advanced Filtration Systems for GDI Engines: Hee Je Seong (Argonne National Laboratory) – Advanced Combustion Engines

Reviewer 1:

The reviewer stated that careful characterization of ash effect on filter performance (back pressure, filtration efficiency etc.) addressed a key issue in gasoline particulate filters, especially related to three-way catalyst (TWC) wash-coated filters

Reviewer 2:

The reviewer explained that this project takes a good approach in characterizing the filtration system for GDI engines. Study and findings with ash loading on gasoline particulate filters (GPFs) of various configurations contribute to the knowledge base of the field. It provides guidance for future design and operation of GDI engine as a system, from filter design to additive considerations for fuel and lube oil. This reviewer also suggested that it would be beneficial if some theoretical work could be included in the future to explain the observations. For example, what is the underlying chemical/physical mechanism that calcium (Ca) presence would enhance soot oxidation?

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the promotional effect of Ca on soot regeneration is interesting. However, it is not clear how the presence of ash would improve soot oxidation with very low oxygen (O_2) availability. This reviewer also suggested that a further investigation to the mechanism seems reasonable.

Reviewer 2:

The reviewer affirmed that good progress has been made with regards to the effects of catalyst/ash loading, porosity of the filter as well as their interactions. Testing tools and methods are excellent, but indicated, however, some of the conclusions are too general from the data presented. For example, the conclusions with regards to ash loading were based on a comparison between no ash and 2 gram per liter (g/L) only. The reviewer questioned if the conclusions would still be valid if the ash loading is 10g/L.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer indicated that collaboration and coordination with Corning, Hyundai, and universities have been good. However, the expertise of the team is limited to filter material, testing and soot measurement and characterization. This reviewer also suggested that in the future, some organization with expertise in the chemical kinetics in catalysis should be included to help to explain the observations.

Reviewer 2:

The reviewer noted that although the industrial partners provided test articles (engine and filters), the project could benefit from more regular technical interactions among the partners.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that it is critically important to gain knowledge on catalyst wash-coat, soot, and ash distribution profiles in high porosity filters, especially for the field aged filters.

Reviewer 2:

The reviewer stated that proposed future work is reasonable. Again, to understand the mechanisms of enhanced soot oxidation the team needs to include a technical expert in this area.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer pointed out that this project addresses PM emission control from a GDI gasoline stoichiometric engine, which offers fuel savings compared to port fuel injection (PFI) engines

Reviewer 2:

The reviewer explained that the findings from this study could help GDI engines in meeting future emissions standard. GDI engines improve fuel economy, which would support DOE objectives of petroleum displacement.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that funding seems to be adequate for the remaining tasks.

Enhanced High- and Low-Temperature Performance of NO_x Reduction Materials: Feng Gao (Pacific Northwest National Laboratory) - ace026

Presenter

Feng Gao, Pacific Northwest National Laboratory.

Reviewer Sample Size

A total of three reviewers evaluated this project.

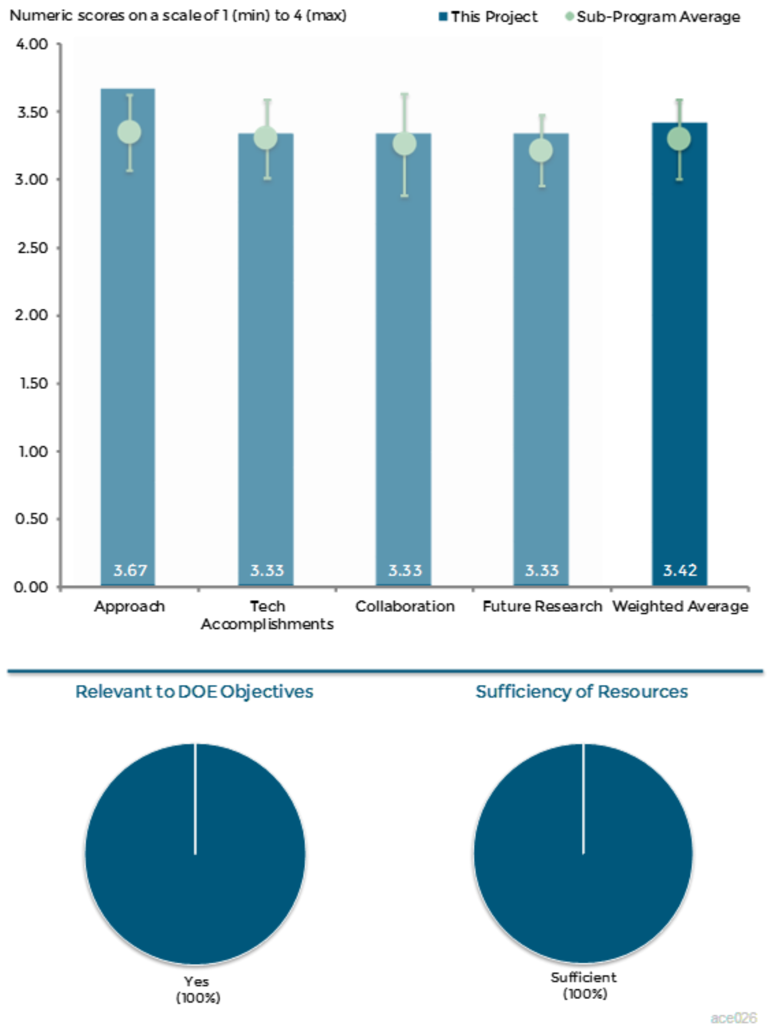

Figure 4-18 Enhanced High- and Low-Temperature Performance of NO_x Reduction Materials: Feng Gao (Pacific Northwest National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer reported that this project takes an excellent approach in addressing the challenges in low-temperature NO_x emissions control. The work performed has been well designed and is of high quality with a clear focus on critical barriers facing the technology.

Reviewer 2:

This reviewer remarked that the approach seems reasonable. Pacific Northwest National Laboratory (PNNL) synthesizes catalysts based on iterative experiments. JM and Cummins provide baseline catalysts and results. The reviewer stated that it is not clear what role JM catalysts play in the scheme. However, these companies are catalyst experts and could be valuable in the collaboration. The reviewer likes the idea of using several zeolite families, analyzing structures and performance, and then tweaking the key parameters to determine effects on performance, and agreed with the shift away from NSR catalysts and fully into SCR.

Reviewer 3:

The reviewer pointed out that further expanding the operating temperature window is an important area for improving SCR catalyst performance, especially after realistic aging.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that new results on Cu loading and Cu/SAPO-34 catalyst are valuable. In addition, optimum Cu loading was determined and explained. There was interesting work reported on Cu/SSZ-13 and cation interactions gives improved performance verses commercial catalyst, with explanation. This reviewer then stated that reducing NH_4NO_3 is important for N_2O reduction and low temperature (LT) performance. Work on mixed Cu and Fe chabazite (CHA) extends previous work and reduces N_2O. The reviewer said it is not clear that LT performance has been improved, which is one of the project's key deliverables. In addition, there are no results on structure/LT performance.

Reviewer 2:

The reviewer agreed that excess Cu loading causing SAPO-34 structure collapse is an important finding and a detailed study is warranted to further understand its mechanism. It is also interesting to see that reaction rates increases in the presence of coactions and the origin of this promotional effect needs to be addressed.

Reviewer 3:

The reviewer commented that good progress has been made in all focus areas. The findings have been very insightful. This reviewer stated that the identification of better SCR catalyst materials than the first generation of Cu/SSZ-13 is a major accomplishment. Synergy between Cu/CHA and Fe/CHA in limiting the N_2O formation is very interesting.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer reported that collaboration and coordination with Cummins and JM was reported and seems to be good.

Reviewer 2:

The reviewer warned that the collaboration seems to be minimal and it appears the project team is not using JM and maybe even Cummins to their full potential. JM has some excellent catalyst understanding and should be more involved than simply providing baseline catalysts. Cummins is providing valuable testing capability and assume feedback into performance deficiencies and strengths. However, the reviewer stated that in the end, the main advantage of having JM and Cummins on the team is to transfer the technology into practice. This is and will be very important.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer observed that the proposed future work follows a well-planned path and is consistent with overall goal of the project. Leveraging with other NSF-DOE funded projects in understanding of catalyst mechanisms and limitations on theoretical bases is a good use of resources.

Reviewer 2:

The reviewer agreed that more work on durability and poisoning on the best candidates, as proposed, is a critical next step. This reviewer then stated that the project has built up significant understanding on processing, structure, and performance effects. The reviewer is not convinced that the project has the best zeolites, yet. This reviewer suggested that there should be leveraging work at Purdue University, University of Notre Dame and the University of Washington where more catalyst formulation work is occurring and incorporates their learnings into further optimization. However, again, in the end the project has made significant progress on understanding the strengths and weaknesses of zeolites and improving performance accordingly. It is difficult to say where the project is on the performance improvement evolution. The reviewer suspected that the project has already achieved perhaps 80-90% of the way to full optimization. Squeaking out that last 15% of optimum performance might be diminishing returns at this stage and perhaps a useful follow-up project after the other laboratories do their work. The reviewer warned that the project has not delivered better LT performance, yet future plans are ignoring this. Maybe further optimization based on improved understanding can be applied here.

Reviewer 3:
The reviewer stated that the work plan seems reasonable. The effect of zeolite acidity on catalyst performance at low and high temperature ranges is an important issue to better understand the surface chemistry and reaction mechanism. This reviewer confirmed that the effect of sulfur and hydrocarbon poisoning is also critical.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer remarked that this project addresses a key enabling issue with regards to LTC engine technology. Low-temperature engines improve fuel economy, which would support DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer commented that $DeNO_x$ means de-carbon dioxide (CO_2) and "de-fuel-consumption" for most HD diesel and lean-natural gas calibrations.

Reviewer 3:
The reviewer affirmed that further improving SCR catalyst efficiency is critical to enable diesel engines to meet future stringent emission regulations.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that $300,000 is a bargain for the progress obtained. Given this performance and the resources of the partners for doing further durability and poisoning tests, no further public moneys appear not to be needed.

Reviewer 2:
The reviewer confirmed that funding seems to be adequate for the remaining tasks.

Thermally Stable Ultra Low-Temperature Oxidation Catalysts: Abhijeet Karkamkar (Pacific Northwest National Laboratory) - ace027

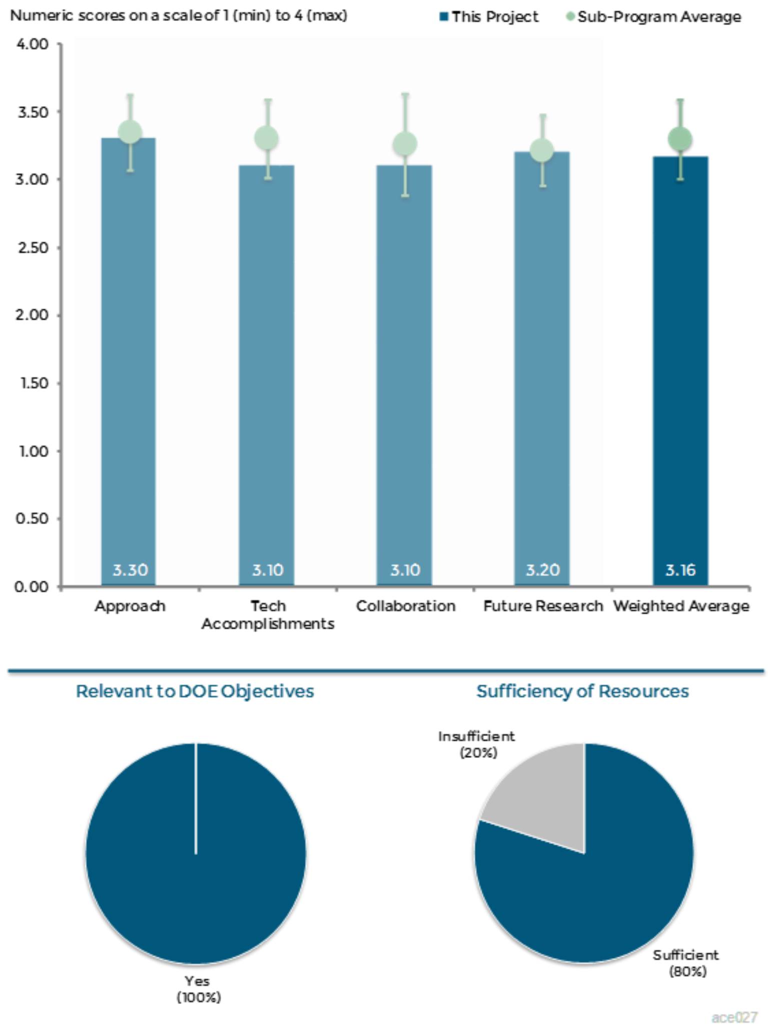

Figure 4-19 Thermally Stable Ultra Low-Temperature Oxidation Catalysts: Abhijeet Karkamkar (Pacific Northwest National Laboratory) – Advanced Combustion Engines

Presenter

Abhijeet Karkamkar, Pacific Northwest National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that this is an excellent approach with requirements of the 150° Centigrade (C), challenging work directly identified from voice of the R&D customer through U.S. DRIVE workshop, with strong recommended technical scoping and requirements from three OEMs, two national laboratories, and DOE VTO. Resulting targets are succinct and relevant; temperature for 50% conversion of CO and hydrocarbon oxidation at 150ºC plus stable performance after 750ºC for 72 hours under 10% H_2O/air representing approximately 120,000 miles. This reviewer commented that excellent focus on non-platinum group metal (PGM) observed; this activity supports an important function of establishing specifications and targets for urea alternatives. Higher density NH_3 storage materials will be needed to obtain the level of NO_x control required for both HD and LD applications without sacrificing the vehicle owner experience. This reviewer also pointed out that currently, there are possible alternatives to urea that must be evaluated from an OEM point of view to determine their viability for use.

Reviewer 2:

The reviewer indicated that it is worth noting that this fairly new project has a different name and topic than that listed in the main agenda, because it now relates to solid NH_3 storage materials and not ultra-low temperature oxidation catalysts. However, the topic that USCAR and PNNL are interested in is a good one. The reviewer explained that the approach of looking at materials is fine, but other factors, including system issues in heating and using the NH_3 from different materials should also be addressed. In particular, choosing an optimum temperature range (less than100 degrees) over which the material begins and finishes releasing NH_3 is the main interest. Materials with high temperature release of NH_3 will cost too much in energy to be useful.

Reviewer 3:

The reviewer remarked that the project is a relatively broad investigation into various solid materials for NH_3 storage, but suggested that the project needs to consider non-chlorine materials that will not produce hydrogen chloride (HCl), as that can potentially cause problems with the catalysts and/or the paint around the exhaust pipe. It was necessary to go away from chloride salts of precious metals years ago because the HCl was causing pitting in the paint around the exhaust pipe.

The reviewer expressed a liking to the idea of a high-density solid source of NH_3, as that would overcome concerns about freezing of the urea solution. This reviewer then questioned how the project team would prevent H_2O from affecting the solid storage material. Even if the NH3 generation is performed in a separate chamber, there has to be a way to inject the NH_3 into the exhaust system. That would provide access for the H_2O from the exhaust to get into the NH_3 storage material. The reviewer asked if the rate of decomposition of the solid material sufficiently fast to provide enough NH_3 on the fly, particularly during periods of high flow rates and high NO_x generation, and then asked if the gaseous NH_3 that is derived from the solid source would have to be stored in a chamber so there would be enough available when it is needed; are there safety concerns about storing gaseous NH_3 on the vehicle; and how much volume would be needed. The reviewer stated that could be a concern on small vehicles (such as in Europe), where packaging constraints are always a concern.

Reviewer 4:

The reviewer suggested that having some conceptual idea of what might be effective might be helpful before preparing and testing samples.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer expressed a pleasure that the project team has identified quite a number of possible candidates. The team seems to be following a tree approach. This reviewer also indicated that doing binary mixtures is good and perhaps ternary will be on this list at some point. The reviewer commented to trudge on.

Reviewer 2:

The reviewer commented that although relative targets and goals were mentioned, well defined targets and goals were lacking in this work currently. These will be necessary to effectively rank the materials for providing NH_3 under the appropriate conditions. Also, realistic assessments of the urea alternatives must be more thought out. For example, downgrading carbamate as a urea replacement, because it yields CO_2 as a decomposition product, is not appropriate. Stating that the CO_2 from the decomposition will recombine in the exhaust at low temperature to reform carbamate is not unique to this material. In fact, any reductant that forms NH_3 in the exhaust has the potential to combine with the readily available CO_2 to form carbamate anyway. Also, the additional CO_2, from the decomposition of carbamate, is a negligible impact on the rated fuel economy. A more important aspect is its decomposition temperature and the density of NH_3 it can support.

Reviewer 3:

The reviewer reported that the results were quite broad over a large material base. It could be used as a means of down selecting materials.

Reviewer 4:

The reviewer observed strong near-term results pointing to possible formulations of low-temperature Cu/ceria-zirconia catalysts for 150°C CO and hydrocarbon oxidation and long term hydro-thermal aging robustness theorized to be due to identified praseodymium (Pr) and lanthanum (La) additives for enhanced structural stability.

Reviewer 5:

The reviewer mentioned that this is a nice study of the decomposition rate of various NH_3 storage materials. Again, need to emphasize non-chlorine materials to avoid the potential for HCl generation.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer observed that there is a very good OEM, national laboratory team with well-defined roles.

Reviewer 2:

The reviewer pointed out that all three OEMs participated in this study, which is essential for writing specifications that will affect their products. However, the inclusion of an industry chemistry thoroughly knowledgeable of reactions involving these NH_3 compounds would provide useful feedback on the metrics used in this work. This reviewer also suggested frequent group meetings to discuss the project progress keep this project focused.

Reviewer 3:

The reviewer reported that good collaboration, but consideration of even broader cooperation would be good at this early stage.

Reviewer 4:

The reviewer observed that there was not a lot of collaboration with other institutions other than USCAR. It was mentioned that an OEM partner was being sought and asked what about partnering with a supplier.

Reviewer 5:

The reviewer expressed a consideration that conference calls every two or three months to be very low collaboration, and suggested it is an industrial's dream, for there is not much work and very few meetings.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that excellent follow on to interesting results to include zircon. This reviewer then concluded that future characterization studies of Cu/ceria-zirconia materials are an excellent enhancement to Cu/ceria effort with potential for improved durability performance.

Reviewer 2:

The reviewer agreed that it is a good choice of material studies, but need to develop clearer criteria for down selection choices.

Reviewer 3:

The reviewer mentioned that the double salts and eutectics could prove interesting. This reviewer highlighted that there is a need to consider materials that will not produce HCl. In addition, there is a need to consider how to prevent H_2O from the exhaust to adversely affect the solid materials.

Reviewer 4:

The reviewer observed that more appropriate targets and goals should be developed as refinement to this work progresses.

Reviewer 5:

The reviewer brought to light that there seems to be little effort to bring a systematic or conceptual approach to this project. The future work follows that mold, but questioned when and if the project team finds an acceptable alternative, will the team know why and will that led the project team to even better choices.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer declared that a solid NH_3 source for an SCR catalyst could increase the use of lean engines for improved fuel economy, particularly in cold climates where there is concern over freezing of the aqueous urea solution. As a result, heat must be used to heat the urea solution, which takes away from the fuel economy.

Reviewer 2:

The reviewer explained that identifying effective materials, understanding and defining mechanisms/limitations for low-temperature performance are critical to designing productive LTC to support new combustion strategies with significant efficiency improvement potential.

Reviewer 3:

The reviewer acknowledged that a good solution would allow greater penetration into the LD market where diesel powertrains would bring greater CO_2 savings.

Reviewer 4:

The reviewer concluded that high density NH_3 storage materials and systems are needed to enhance the use of lean aftertreatment systems that are increasingly becoming a part of OEM fleets' to achieve fuel economy requirements. Extending the vehicle range between refilling the reductant is important from a packaging point of view and owner experience.

Reviewer 5:

The reviewer mentioned that materials allow for less energy use at cold start.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that there is no evidence that the funding is insufficient for the experimental work. This reviewer also expressed a need for a conceptual component and that will probably require additional resources.

Reviewer 2:

The reviewer acknowledged that resources are appropriate, no additional personnel or funding required.

Cummins/ORNL-FEERC CRADA: NO_x Control and Measurement Technology for Heavy-Duty Diesel Engines: Bill Partridge (Oak Ridge National Laboratory) - ace032

Presenter

Bill Partridge, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

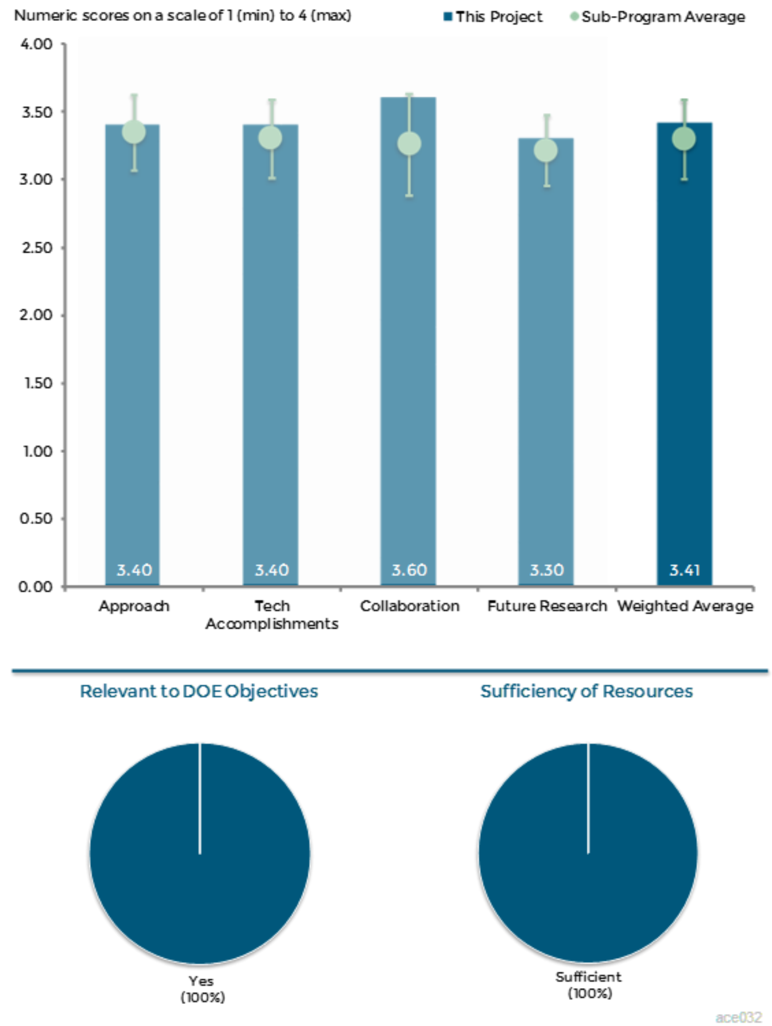

Figure 4-20 Cummins/ORNL-FEERC CRADA: NO_x Control and Measurement Technology for Heavy-Duty Diesel Engines: Bill Partridge (Oak Ridge National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work–the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer reported that the project has an excellent approach to improve understanding of mainstream catalysts, catalyst aging with large contingency from industry CRADA.

Reviewer 2:

The reviewer agreed that the project has a good approach with a wide range of methods, especially spatially resolved capillary inlet Spaci-based.

Reviewer 3:

The reviewer remarked that it is an interesting approach of using Spaci to study the effects of field aging on the NH_3 storage capacity and NO_x conversion down the length of the sample. There needs to be a study on the effects of field aging on the front, middle, and back of the entire catalyst length (for example, not just the front of the front brick) and also from the middle and non-middle sections of the bricks (for example, the middle can be aged more than the non-middle of the bricks due to non-uniformity of the flow through the catalyst, especially at high loads and high flow rates). This reviewer observed that there is a need for a better definition of the field aging, like the number of miles (or hours) and the temperature histogram during the aging. The reviewer questioned if the catalyst was exposed to 1,000 miles of low temperature driving or 100,000 miles of high temperature driving. This reviewer also mentioned that there is a clue as to the severity of the aging.

Reviewer 4:

The reviewer reported that this project is always hard to review, and always goes back to see where the team said they would go, and wonders how the team got here. However, the result is always great even though the path is sometimes unclear, and, consequently, would never fault the approach.

Reviewer 5:

The reviewer pointed out that Spaci-MS tools are important for understanding the reactions occurring along reaction pathway and how NH_3 adsorbs and where it adsorbs. The approach provides helpful information of how much catalyst volume is needed as well as the effect of different species on the reactions themselves. This reviewer cautioned that this has been done by others as well, and questioned if the project team is reproducing this work. Aging effects also included in this work and its effect on reaction and storage.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer affirmed that the project has excellent studies of NH_3-SCR reaction and its field aged performance in its range of topics.

Reviewer 2:

This reviewer mentioned that the project has solid technical accomplishments to target for field aging and modeling study.

Reviewer 3:

The reviewer remarked that there was a very interesting breakdown of the total NH_3 capacity, dynamic NH_3 capacity, and unused NH_3 capacity. The project clearly points out that field aging is more severe on the NH_3 storage capacity than hydrothermal aging. This reviewer also questioned if there are plans to modify the hydrothermal aging procedure to better match the field aging. This might prove difficult, as the field aging is going to age the catalyst non-homogeneously (for example, ages the front more than the back and the middle more than the non-middle), which hydrothermal aging will age the entire volume uniformly.

Reviewer 4:

The reviewer commented that as always very helpful. The reviewer confirmed that the clarity on NH_3 storage in SCR catalysts will be very helpful in the modeling.

Reviewer 5:

The reviewer highlighted that understanding the effects of field aging (FA) on how a SCR function is lost is critical to developing SCR-based NO_x control systems. Including transient behavior in the study is also important for emulating vehicle operation and that effect on SCR activity. This reviewer brought to light that the work by others like GM and ORNL have shown the aging effects, so some of the work is completed by others already.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer applauded the excellent collaboration, with multiple OEMs and universities supporting the work.

Reviewer 2:

The reviewer observed that the combination of Chalmers, Milano and Cummins is a who’s who of SCR investigations.

Reviewer 3:

The reviewer acknowledged that the range and quality of collaborators in this project is one of its main strengths.

Reviewer 4:
The reviewer expressed an agreement that Cummins is a very appropriate partner for this project for HD applications and suggested for LD applications, inclusion of an automotive OEM would be an additional benefit.

Reviewer 5:
The reviewer suggested that some comments on Cummins' contributions would be helpful other than supplying the field-aged catalyst.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer praised that the good choice of topics to take the project forward.

Reviewer 2:
The reviewer mentioned that it is solid proposed work to meet a very good plan. Part of current objectives that could be enhanced in future work is to identify strategies for catalyst-state assessment. This is very critical work for dynamic NH_3 storage and also related to aging. This reviewer concluded that the specific approaches and models to assist application engineering for catalyst formulations could be outstanding future work.

Reviewer 3:
The reviewer expressed a hope to see this project continued.

Reviewer 4:
The reviewer concluded that this work appears to be incremental rather than innovative, which is expected from a national laboratory. This reviewer also questioned if this work can be performed by industry.

Reviewer 5:
If the work is extended, the reviewer suggested that the statement of work should include a better characterization of the effect of aging along the axis and across the radius of the catalyst.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer confirmed that SCR is the technology for NO_x control in diesel engines and may become common in lean gasoline NO_x control. It allows those engines high fuel economy while meeting engine standards.

Reviewer 2:
The reviewer said that yes, SCR NO_x control systems are the leading technologies for meeting future emissions standards for lean diesel vehicles.

Reviewer 3:
The reviewer observed that aftertreatment strategies, modeling, and durability to enable the use of advanced combustion strategies to achieve nominally between 6-15% improvements in fuel consumption.

Reviewer 4:
The reviewer pointed out that a better understanding of the effects of field aging is needed to design systems that can improve the fuel economy (and thereby lower petroleum usage) while meeting strict emission standards with cost-effective aftertreatment systems.

Reviewer 5:

The reviewer concluded that improved performance even after field aging will be benefit.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer specified that equivalent or even more resources should be expended in the next phase of the project.

Reviewer 2:

The reviewer reported that the resources, both funding and personnel, are appropriate for the scope of this project.

Reviewer 3:

The reviewer agreed that resources for current targets are sufficient at level of good to excellent. Outstanding results for modeling and strategies for catalyst state assessment likely will require additional funding.

Emissions Control for Lean Gasoline Engines: Jim Parks (Oak Ridge National Laboratory) - ace033

Presenter

Jim Parks, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

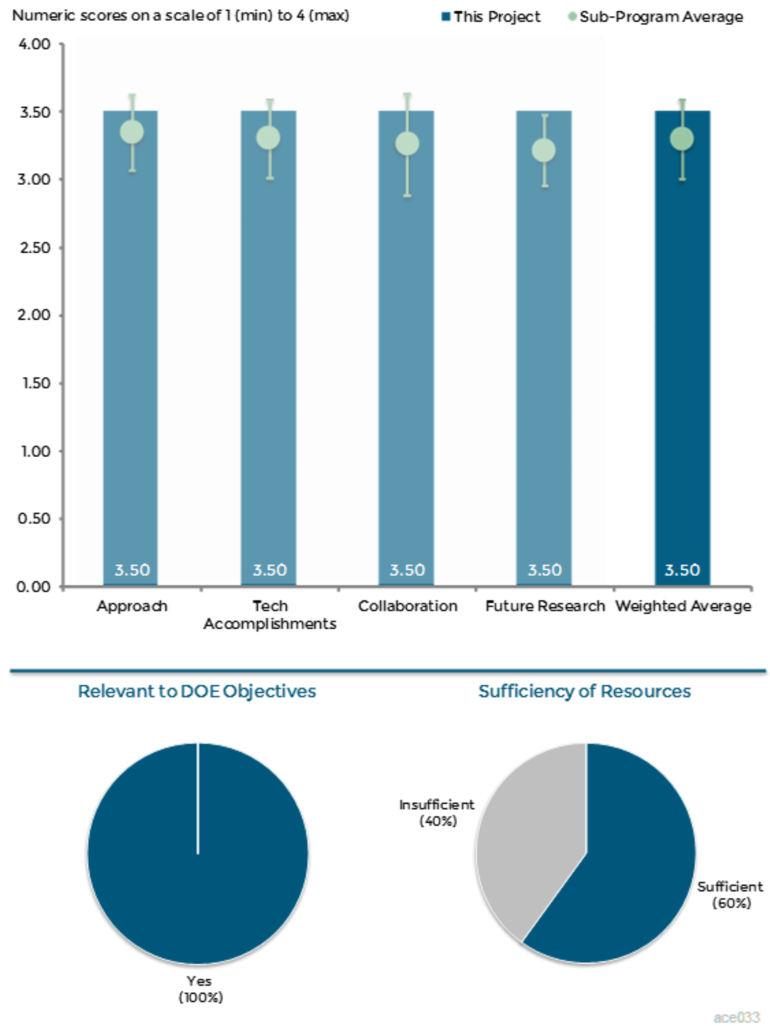

Figure 4-21 Emissions Control for Lean Gasoline Engines: Jim Parks (Oak Ridge National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that this project is excellently conceived and designed to reach answers to the questions it asked about lean gasoline emissions control. The choice of conditions and catalysts was well done.

Reviewer 2:

The reviewer emphasize that d an excellent approach continues to evolve as emissions standards tighten up and feedback is presented. Precisely defined metrics include targets for fuel economy improvements over stoichiometric operation for each funding year as well as platinum group metal (PGM) count reductions. The reviewer specified that feedback from OEMs on value of passive systems, lessons learned and technical challenges would improve rating to outstanding. Several OEMs indicate passive system challenges are constraining use especially predictability of efficiently producing NH_3. The reviewer suggested sensitivity analysis in system modeling.

Reviewer 3:

The reviewer observed that this project benefits greatly from combining bench reactor results with appropriate engine testing. This is an excellent way to quickly determine the benefits of emerging technologies, under realistic conditions, and to assign cause and effect seen with vehicle testing. This reviewer concluded that this method of R&D has high value.

Reviewer 4:

The reviewer observed that there is a good combination of reactor testing and vehicle testing. It is also good to look at thermal aging and sulfur poisoning effects on the system. This reviewer also warned that the decrease in NH_3 production from the TWC with sulfur poisoning is a concern. One would need to de-sulfate the TWC periodically, and this will generate additional HC and CO emissions that must be integrated into the Federal test Procedure (FTP) emissions, requiring even lower emissions during the FTP. The reviewer suggested there is a need to consider PM emissions, especially for stratified charge. This might require a GPF, which would increase the back-pressure and therefore degrade the fuel economy. The reviewer noted that the rich times on the reactor are long. Need to be on the order of 5 to 10 seconds on the FTP.

Reviewer 5:

This reviewer mentioned that nitrous oxide (N_2O) formation over the TWC was commented on by a prior reviewer; however, no results are reported. The N_2O is produced usually when the gas composition over the oxidation catalyst (especially high Pt) is rich, or when the temperature is high 500-600° in the SCR catalyst (Bartley & Sharp SAE 2012-01-1082). The reviewer concluded because the N_2O limit is penalized over a value of 10 mg/mile, the aftertreatment integrated value is the crucial value. Calibration needs to spend minimal time in high N_2O formation regimes for both the TWC and the SCR. The reviewer suggested a little commentary would be appreciated.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer confirmed that substantial progress has been made, and especially liked the work on the relation of engine conditions (i.e., calibration) to the effectiveness of the NH_3 production. However, it is known that increasing the NO_x can also increase the N_2O. However, the rubber meets the road when the integrated system is tested under transient calibration conditions.

Reviewer 2:

The reviewer confirmed that the reviewers from the OEMs can greatly appreciate research, such as this, that considers the effect of aftertreatment technology on fuel economy in addition to emission control. These twin challenges must be met together. Also, including the effect of sulfur and other exhaust species on the overall catalyst efficiency is very important, because these exhaust components will be present going forward. In addition, bench reactor studies on the effects of regeneration methods helps provide guidance for the implementation of these passive NO_x control strategies to meet emissions standards. The reviewer pointed out that, however, all aspects of a catalyst system must be included in the assessment of fuel economy, and said that with respect to the TWC + NO_x storage, sulfur regeneration must be accounted for in the fuel economy calculation.

Reviewer 3:

The reviewer reported that there was good investigation into the effects of temperature, rich lambda, formulation, and sulfur effects on the NH_3 yield. It was pointed out there is a need to be clearer about the effects of the TWC formulation on the NH_3 production; for example, how much ceria was in the catalyst and what was the PGM loading. This reviewer also indicated it is hard to remember all the details from the table. The reviewer mentioned that there is a need to explore the CO and HC emissions more during the rich periods. The SCR catalyst will not convert CO during rich operation, and by definition one has to go rich over the TWC to generate NH_3. So there will be CO slip during the rich periods. It is suggested a multiple-step purge profile can mitigate the CO concerns. The reviewer remarked the project showed essentially 100% HC conversion during the rich periods. This reviewer then questioned if the project is really getting 100% steam reforming activity from the TWC, especially with the long purges. The reviewer brought to light the project would like to use a non-ceria TWC for NH_3 generation. But it was pointed out there must be some oxygen storage capacity (OSC) in the TWC for three-way activity, steam reforming and water-gas-shift activity, catalyst durability, and OBD diagnostics.

Reviewer 4:

The reviewer agreed that the evaluation of the catalysts and conditions chosen revealed a system that may work well for these engines. The role of rhodium was not revealed as clearly as one would hope, but one system worked well. It would be useful to have more understanding of the role of rhodium, say, in the selectivity of the system.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:
The reviewer highlighted that excellent collaboration with strong OEM partner, national laboratory and consortium/university support through CLEERS is hard to improve. This reviewer also mentioned the project team has an outstanding, active consortium of OEMs and/or Tier 1 to solve this challenging system problem.

Reviewer 2:
The reviewer remarked that good collaboration between General Motors, ORNL, and Umicore.

Reviewer 3:
The reviewer pointed out that working directly with an OEM and catalyst supplier, as in this project, is a high value partnership. Input from these partners is essential for providing the correct testing conditions as well as appropriate catalyst technologies to explore for providing the twin benefits of fuel economy and emission control.

Reviewer 4:
The reviewer agreed that there is a good group of industry, national laboratory, and company researchers worked collaboratively in a constructive way.

Reviewer 5:
The reviewer cautioned that evidence of collaboration is relatively weak. Chris Rutland of UW has done considerable modeling of this type of catalyst and has made predictions of NH_3 and N_2O. This reviewer then suggested that it would be helpful if these results were at least compared to his model.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer observed an excellent approach to complete work on aging, bench flow catalyst optimization, and system efficiency work. More emphasis on system optimization models and approaches that are easily calibrated to for a particular application would make this outstanding.

Reviewer 2:
The reviewer reported that including the effects of fuel poisons on the performance of catalyst efficiency and selectivity is essential research for achieving increasingly stringent emissions standards. In addition, inclusion of emerging hybrid catalyst technologies to study their benefits or drawbacks is important to arrive at emission control systems that minimize the direct impacts on fuel economy and those that occur through greenhouse gas penalties. This reviewer then concluded that these hybrid technologies are quite possibly the enablers for meeting the emissions needs of the OEMs.

Reviewer 3:
The reviewer highlighted that an excellent plan for combined bench and engine work has been put forward.

Reviewer 4:
The reviewer observed that learning how to effectively calibrate the engine is a crucial goal.

Reviewer 5:
The reviewer suggested that there is a need to consider PM emissions. The need for a GPF would negate some of the FE improvement from lean operation and also add a lot of cost to the system. There is also a need more exploration on the HC and CO emissions during the rich periods. The HC emissions are more of a challenge than the NO_x emissions due to the extremely low levels allowed (for example, the cold start eats up most of the allowed HC), although the Tier 3 standards offer some flexibility with the HC and NO_x.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that general adoption of lean passenger cars would have huge impact on gasoline usage.

Reviewer 2:

The reviewer agreed that emission treatment of lean gasoline will provide petroleum displacement.

Reviewer 3:

The reviewer explained that the project incorporates work on the twin challenges of increasing fuel economy while meeting increasingly stringent Tier III and super low-emission vehicle emissions standards.

Reviewer 4:

The reviewer observed that successful lean burn aftertreatment strategies will enable an estimated near-term fuel savings of between 6% and 15% from lean burn combustion. Combustion technologies are available immediately, however, without effective after treatment, the benefit of these advanced combustion techniques cannot be realized in the production fleet.

Reviewer 5:

The reviewer stated that increased use of lean gasoline applications would decrease fuel usage.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer reported that good funding for excellent work. To achieve an outstanding effort, more funding and effort should be placed on system modeling and testing for NH_3 production to improve predictability of production and reduce complexity for OEM implementation.

Reviewer 2:

The reviewer expressed a need to see modeling added to this project.

Reviewer 3:

The reviewer pointed out that ORNL provided significant results with the resources the team has employed to align bench reactor results and engine dynamometer data. Very useful information has been provided for the resources dedicated to this work.

Reviewer 4:

The reviewer confirmed that the resources appear to be sufficient.

Neutron Imaging of Advanced Transportation Technologies: Todd Toops (Oak Ridge National Laboratory) - ace052

Presenter

Todd Toops, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

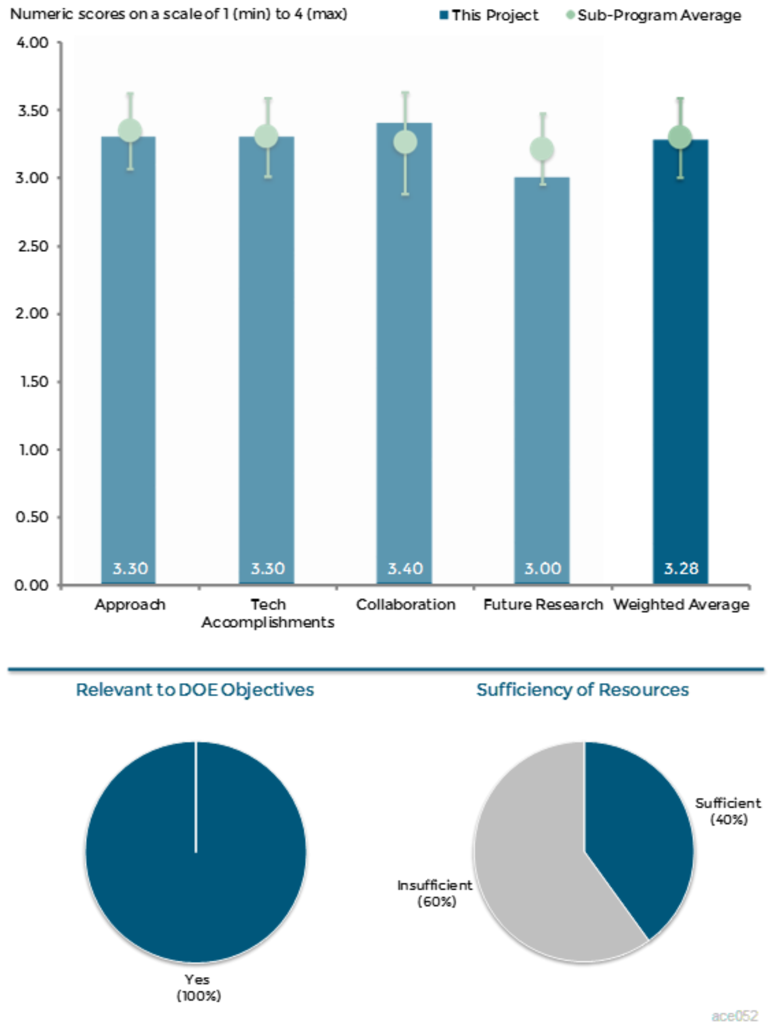

Figure 4-22 Neutron Imaging of Advanced Transportation Technologies: Todd Toops (Oak Ridge National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work–the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that it was good to see gasoline injector related topics included in the work.

Reviewer 2:

The reviewer observed that the development of the neutron imaging as a complimentary tool is quite interesting, as non-destructive analysis or dynamic analysis of injectors (and particulate filters) to this level of understanding is unique. The method to develop these tools seems appropriate, which is evident in the test data that exists. What is not identified is the anticipated direct correlation to reduced fuel consumption with this tool, though it is understood that a quality improvement is possible when understanding lacquering of injectors or fouling of nozzles. This reviewer questioned how the efficiency improvements will be accomplished. The reviewer suggested that partnership with suppliers or OEMs to identify the top two or three issues with the technology could be done. To find a problem that needs solved related to efficiency or durability of components and then pursue that improvement would be interesting.

Reviewer 3:

The reviewer summarized that this is one of those unique projects that is focusing on bringing a new diagnostic for assessing the impact of clogging on injectors and aftertreatment devices. It has been exploratory in nature and the PI's approach has been with care given the possible environmental effects from the measurement technique. This reviewer then pointed out that much work is still needed to mature this diagnostic.

Reviewer 4:

The reviewer mentioned that this is a very interesting project that is using a non-destructive method to study injector characteristic DPF ash loading.

Reviewer 5:

The reviewer asked whether the project team has scoped out the limits of this unique diagnostic after five years of work on neutron imaging.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer reported that the technical accomplishments are very good, with impressive results. The reviewer expressed a reason of why not to mark this as outstanding, is because of the translation of tool development to overcoming barriers is not complete or unclear, and added the included questions of how this will improve particulate filter regeneration efficiency, fuel injection or combustion efficiency, and fuel injector or exhaust after-treatment system (EATS) component durability.

Reviewer 2:

The reviewer said that there were very interesting results from the fouled injector. The injection movie is exciting, but the reviewer is not sure that there is adequate resolution to be very useful. This reviewer then expressed a need to know what can be done to improve the detail in the images.

Reviewer 3:

The reviewer observed that the images generated from this diagnostic have been thought provoking and insightful for better understanding the capability of the current instrumentation. There is still much development work that is necessary including better resolution for studying clogged fuel injectors. This reviewer mentioned that the dribble portion of the work was interesting though the chamber pressure was very low compared to real world GDI applications and thus this observation may have been just a demonstration of the capability of this diagnostic.

Reviewer 4:

The reviewer remarked that characterizing a fouled injector was interesting, given the small size of the injector holes. Dynamic fluid flow videos captured inside the injector and coming out of it had low resolution, which makes it not very useful for model development. It is not very clear how any quantitative feedback for the modeling effort can be created. This reviewer expressed an agreement that evaluating ash loading is also a good application of this diagnostic technology.

Reviewer 5:

The reviewer pointed out that the non-destructive testing of clean and fouled injectors is very impressive and encouraging. Neutron imaging is certainly living up to its promise of being a non-destructive testing technique. The work on visualizing ash distribution within particulate filters is also revealing very interesting results. The reviewer indicated the visualization of the dynamic fuel injector is also interesting and questioned if the resolution can be improved.

Question 3: Collaboration and Coordination with other institutions.

Reviewer 1:

The reviewer highlighted the fact that there is excellent collaboration with industry, DOE Basic Energy Sciences (BES), suppliers, universities and national laboratories.

Reviewer 2:

The reviewer praised that the PI for having done a great job bringing together various partners to assess the capability of the diagnostic. Hopefully various partners will continue to supply test articles.

Reviewer 3:

The reviewer mentioned that it seems the an appropriate team is built to accomplish the development of the tool and first use, but now perhaps a consideration should be made to ensure a real problem is identified and solved, which may or may not require the addition of further members to the team.

Reviewer 4:

The reviewer said that it was good to see collaborations with industry partners.

Reviewer 5:

The reviewer reported that given this project aims to demonstrate a very unique and novel technique, sufficient collaboration exists.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer agreed that the proposed research is very good. The only suggestion is to consider including high-pressure common rail injectors in future studies.

Reviewer 2:

The reviewer mentioned that the proposed future work seems appropriate but does not seem concrete. The focus will be on fuel injectors and extreme conditions but perhaps this is not the direction this study should really be pursuing. This reviewer then suggested that the project could benefit from input from suppliers and manufacturers to identify a problem that needs to be understood and resolved, to ensure too much effort is not wasted on pursuing conditions that are not impacting today or future products.

Reviewer 3:

The reviewer pointed out that the need to identify areas of research that neutron imaging can uniquely access such as the particulate filter work. It is not clear yet if this is a good technique for imaging injector sprays.

Reviewer 4:

The reviewer remarked that some feedback on the cost of this neutron imaging diagnostic capability would be useful to understand. If this develops into a very reliable diagnostic capability, then the reviewer questioned how can industry injector and aftertreatment suppliers have access to this, or even own such equipment.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer affirmed that this project indirectly supports DOE objectives. It is an infant project that has potential to aid in the development of future injectors and aftertreatment devices for fuel efficient engines.

Reviewer 2:

The reviewer observed that fuel injectors and particulate filters are core components and improving upon them is vital for further efficiency gains.

Reviewer 3:

The reviewer confirmed that the project can help diagnose component behavior related to engine efficiency.

Reviewer 4:

The reviewer acknowledged that yes, this neutron imaging capability has several useful applications for characterizing engine injectors, which in turn would validate models required for understanding fundamental engine physics.

Reviewer 5:

This reviewer mentioned that the project addresses some of the risks associated with introducing some of the hardware for high efficiency engines.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the fiscal year 2015 presentation showed promising results. This effort should be expanded.

Reviewer 2:

The reviewer stated that the resource level seems appropriate.

Reviewer 3:

The reviewer indicated that there is a need to do more work in this area to identify other components that can be imaged and improve the image resolution.

Reviewer 4:

The reviewer suggested that possibly exploring high resolution measurement capability would be of value for future injector studies. This might be a good investment.

RCM Studies to Enable Gasoline-Relevant Low-Temperature Combustion: Scott Goldsborough (Argonne National Laboratory) - ace054

Presenter

Scott Goldsborough, Argonne National Laboratory.

Reviewer Sample Size

A total of four reviewers evaluated this project.

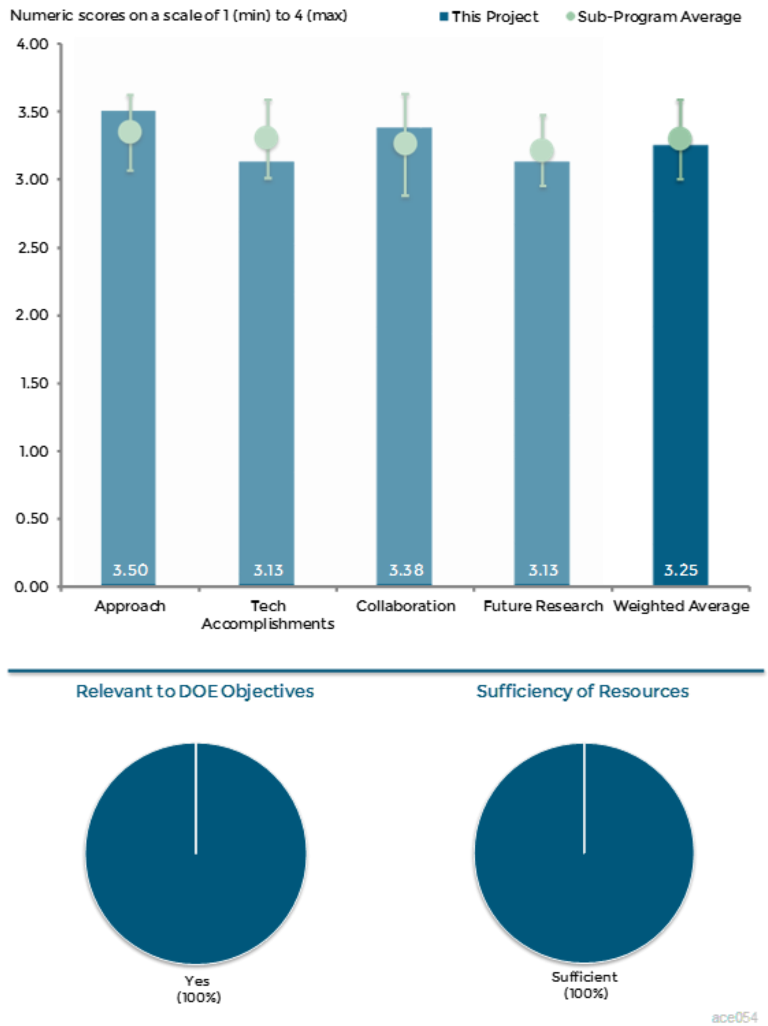

Figure 4-23 RCM Studies to Enable Gasoline-Relevant Low-Temperature Combustion: Scott Goldsborough (Argonne National Laboratory) – Advanced Combustion Engines

Reviewer 1:

The reviewer reported that the project has developed an excellent approach to overcome the technical barrier of inadequate chemical kinetic modeling capability for low-temperature combustion. The reviewer added that the novel data analysis (Uncertainty Quantification [UQ]/Global Sensitivity Analysis [GSA]) tools and new diagnostic capabilities effectively aid chemistry development via twin-piston RCM experiments. The reviewer stated that the project approach clearly addresses a significant technical barrier. The project is well designed in terms of systematic experiments and analysis for various fuels and surrogate blends and the approach seems feasible based on the progress so far. The reviewer noted that improved chemical kinetics models are a crucial and integral part of engine simulations needed to develop improved engines, the success of this endeavor will surely benefit the entire engine community.

Reviewer 2:

The reviewer observed that the use of machine RCM to acquire auto-ignition and fundamental data to develop chemical kinetics for gasoline fuel in conditions representative of internal combustion engine (ICE) is a good approach. The reviewer added that the project was able to acquire combustion data at pressure levels closer to actual in-cylinder pressure levels, which is important.

Reviewer 3:

The reviewer stated that this project involves the acquisition of data that will assist in the validation of chemical kinetic models as inputs to codes used to predict performance of transportation engines. The main tool is the RCM. The PI is a leader in this field and his RCM is outfitted with diagnostics that provide state of the art measurements. The reviewer added that the approach is to perform experiments on gasoline surrogate fuels and to obtain data that seems to be primarily ignition delay time, which the RCM is well positioned to obtain. As far as could be determined, the main output of the experiment that would be used in modeling is the ignition delay time (IDT). The reviewer said that the PI is in position to provide among the most accurate measurements of this type that modelers could use. In addition the reviewer commented that the PI is using the

RCM to assess performance of E0, E10 and E20. This is understandable because these fuels are currently being used. The reviewer noted that at the same time it would be appropriate to be more forward thinking and examine performance of other gasoline blends, such as gasoline with butanol (i.e., 0% butanol, 10% butanol, and 20% butanol).The reviewer added that the IDT is popularly used in codes that assess performance of kinetics. Such data are obtained in shock tubes, or RCMs as in this study, with temperature regimes that are complementary. The reviewer indicated that it is important to note that the IDT is but one of a number of metrics used to validate combustion chemistry. Others include laminar flame speed, extinction strain rate, etc. It would help if the PI could provide a context for the IDT and why the PI believes it is the most important, or very important. The reviewer observed that the plan for leveraging with the DOE Basic Energy Sciences (BES) researchers is excellent. More of this should be encouraged and similarly for other national laboratories.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the enhanced physical model to represent the RCM when calibrating chemical kinetics is important. The reviewer added that progress was made in acquiring and analyzing auto-ignition data sets.

Reviewer 2:

The reviewer indicated that progress took a hit this year as several components of the twin-piston RCM had to be redesigned to increase reliability and accuracy, but significant results were still obtained in several areas. The reviewer noted that key physical insights relevant to low-temperature combustion were obtained from experiments on gasoline/ethanol blends, and new UQ/GSA models were developed that are now tractable via various software tools. The reviewer added that areas of challenges and improvements in terms of accounting for the correlated uncertainties are also properly identified. All the above technical accomplishments are clearly aligned to the overall project objectives of improving chemical kinetic modeling capability, and the overall U.S. Department of Energy (DOE) goal of predictive engine simulations.

Reviewer 3:

The reviewer said that there was some connection to engine level combustion. The reviewer stated that the project team needs to continue applying techniques and results to engine level attributes.

Reviewer 4:

The reviewer stated that it is very interesting that there is no difference of the IDTs in the high temperature regimes, for example, less than 900,000, while significant differences are found at lower temperatures. The reviewer asked is this result consistent with performance of these fuels in engine tests, for example, for other metrics. The reviewer added that it was not clear precisely what code is being used in the CHEMKIN simulation and what rationales would be brought to bear to reduce the combustion chemistry from 7,000+ steps to a more computationally manageable number. The reviewer asked if the code (whatever it is) could handle 7,000 reactions in a reasonable computer time. In addition the reviewer asked are special computers needed to perform the calculations (photos of what look like Lawrence Livermore National Laboratory (LLNL) computers were included in the slides but it was not clear what these were). The reviewer asked what the computational time was. The reviewer also asked what the computer platform was. The reviewer noted a fast kinetic solver but it was not clear what this was. The reviewer then asked is developing such a solver part of the work or does it already exist. The reviewer also noted constant volume simulations where the simulations were compared with measurements. The reviewer asked what the relevance of a constant volume configuration is here. The reviewer also asked if the constant volume configuration is to provide a fundamental environment for combustion or is there more to it. In addition the reviewer asked would the chemistry validated with constant volume or RCM data carry over to the engine environment where a different code would presumably be used, for example, KIVA, Converge, etc. The reviewer noted that the iso-octane simulations show a rather strong effect of preheating the gas (for example, the initial temperature), this needs to be explained.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that the workshop concept, inspired by the ECN no doubt, is an excellent way to engage labs, universities, energy companies, and engine makers. The action to expand the workshop to include some of the other experimental devices important for kinetics research (shock tubes, etc.) is very commendable and addresses a reservation that this reviewer voiced last year. The reviewer added that beyond the workshops, there is significant collaboration within the project on a more detailed level.

Reviewer 2:

The reviewer commented that Argonne National Laboratory (ANL) leads the international RCM workshops which enables collaboration and standardization of RCM experiments for kinetics development.

Reviewer 3:

The reviewer indicated that this project has a lot of collaborators. The PI has developed successful workshops based on RCM data. Presumably at these workshops some of the questions noted previously might have been addressed and the reviewer asked if the questions were addressed. The reviewer noted that the input these collaborators provide was not clearly stated beyond a few sentences. For example, reviewers read mechanism reduction for Northeastern, gasoline surrogate model for LLNL, fuels, fuel models for KAUST, etc.. The reviewer stated that these words do not provide much useful information for how their inputs are critical to the success of this project. The reviewer would like to know precisely what these organizations are substantively contributing to this project, and how necessary their input is.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the future work has been planned effectively to improve the model capabilities and planning additional RCM experiments with sufficient level of detail (step-by-step procedures) addressed; however, the reviewer said that the individual timelines of the proposed action items should be more clearly defined, and future work should also look into quantitative comparisons of the improved chemical kinetics model with the existing ones.

Reviewer 2:

The reviewer indicated that further RCM experiments to model gasoline and gasoline surrogates were needed.

Reviewer 3:

The reviewer reported that for future work the PI wants to study a low order surrogate blend that can contain up to 10 components, though it would seem that 10 is not a particularly low order surrogate. The reviewer added that it was not clear what particular surrogate blend was targeted for study. A five-component blend is noted, though the rationale for its selection was not given. The reviewer indicated that the future work notes the need to improve the capabilities of gasoline surrogates. However, the plan to this end is not described in any substantive detail. Presumably, it would involve measuring the IDT, predicting it using some sort of code of the RCM, and comparing the results. The reviewer asked, but then what. The reviewer then asked what the plan is going forward if the code does not well predict the IDT data. The reviewer also asked what code inputs will be adjusted and how. The reviewer recommended that the PI give consideration to a more traditional surrogate, iso-octane/heptane/toluene with variations of the mixture fractions covering regimes of interest (the project team already has iso-octane data). The chemistry of such a blend should be known. The future plan mention some collaborators, for example, naphthenes [KAUST] for multicomponent blends. The reviewer asked what does this mean. Regarding fuels for advanced combustion engines (FACE) fuels with LLNL, the reviewer asked what does this mean. The reviewer then asked if these organizations are going to do some experiments. The reviewer also asked what their role is in the tasks going forward. The reviewer explained that for a given fuel system it would be illustrative to put the PI's IDT data from the RCM on the same plot as shock tube data of the same fuel system.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer stated that this fundamental research is required to develop combustion models.

Reviewer 2:

The reviewer commented that better kinetics will lead to better engine simulations to aid in the design of more efficient engines using less petroleum.

Reviewer 3:

The reviewer stated that the RCM is a valuable tool that provides IDT data to validate the combustion chemistry of surrogates for real transportation fuels. The reviewer added that a close link to developers of simulation codes (KIVA, Converge, etc.) benefits this work because the IDT data are ostensibly going to be used to improve surrogate fuel chemistry, and such chemistry is the input to simulation. The reviewer noted that it is good that the PI is working toward using IDT data to evaluate surrogate chemistry for use in an engine solver.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer reported that the resources seem to be adequate. The reviewer added that the comparatively large ($500,000) cost is likely due to the experimental emphasis of this project, though further details would be useful to better understand what the costs are being used for.

Reviewer 2:

The reviewer said that the resources seem adequate.

Fuel-Neutral Studies of Particulate Matter Transport Emissions: Mark Stewart (Pacific Northwest National Laboratory) - ace056

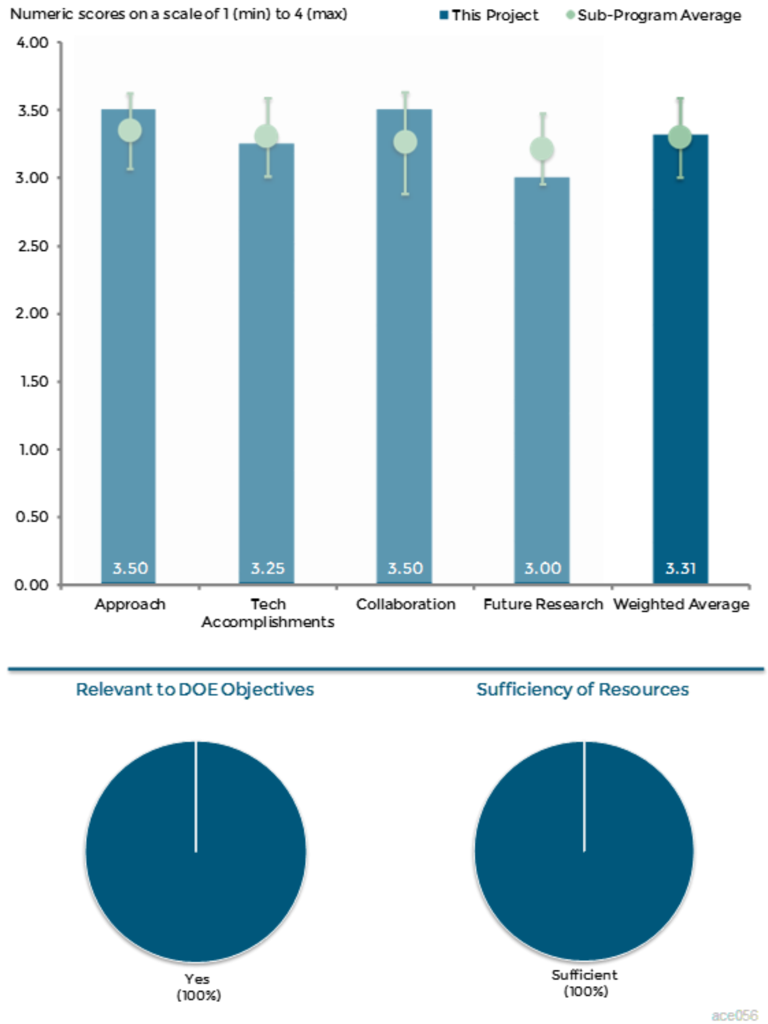

Figure 4-24 Fuel-Neutral Studies of Particulate Matter Transport Emissions: Mark Stewart (Pacific Northwest National Laboratory) – Advanced Combustion Engines

Presenter

Mark Stewart, Pacific Northwest National Laboratory.

Reviewer Sample Size

A total of two reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the work with Engine Research Center (ERC) is impressive. Transfer of equipment to engines and fuels expert testing is world-class. Leveraging ERC's wafer methods also important. The reviewer added that the critical equivalence ratio approach is interesting and important. The reviewer noted that the particle characterization studies seem to address key properties - size, solid content, SOF.

Reviewer 2:

The reviewer indicated that this project takes a comprehensive approach in characterizing the particulate matters for gasoline direct injection (GDI) engines using various fuels and at various engine operating conditions. The reviewer added that the explanation of using non-catalyst-coated filter for the study is reasonable for this stage of the study. Study and findings could provide guidance for future design and operation of gasoline particulate filters (GPF).

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that good progress has been made with regards to the experimental work. The reviewer reported that the technical accomplishments in this area have been impressive. There was little mention of modeling work. The reviewer added that it is not clear to what level the experimental results have improved the feasibility or provided direction of change in the proposed model.

Reviewer 2:

The reviewer remarked that particulates are complex. The reviewer explained that the industry is just now entering a gasoline particulate concern. These fundamental studies on gasoline particulate drivers are important to guide future direction. The reviewer added that critical equivalency ratio data is an interesting approach and confirms the polycyclic aromatic hydrocarbon (PAH) particulate matter (PM) precursor theories established years ago. (California Air Resources Board [CARB] limits PAHs for this reason.) The reviewer noted that there was interesting base-knowledge work on particulate characteristics versus fuel and operating conditions. This data will help guide public policy risks for unfiltered exhaust and fuel directions. Results show that engine operating conditions might have an equal or greater impact on composition and size than fuels. The reviewer stated that the filter results are interesting, but not surprising, yet. The reviewer indicated that the results confirm much of the understanding developed on diesel. The reviewer added that work on filter properties versus performance will be important, there is a good range of filter properties. The reviewer acknowledged that shape versus size filtration efficiency for one filter type is interesting.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that Pacific Northwest National Laboratory (PNNL) and ERC working with filter suppliers is excellent. The reviewer added that there was close collaboration between two key parties. The reviewer said it does not get better than working together on site. The reviewer added that communication with filter suppliers is good.

Reviewer 2:

The reviewer said collaboration and coordination with General Motors (GM) and UW ERC have been good.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the proposed future work is in the right direction. This is a multi-variable problem, and there is an infinite number of combinations. The reviewer added that a careful planning and statistical design of experiments would speed up the project.

Reviewer 2:

The reviewer stated that the continuation of efforts seems logical. When looking at filter effects, start with very different filters to see if GPF properties have an impact. The reviewer pointed out one key oversight, all gasoline engines will have a catalyst, either before or on the GPF. The reviewer asked if the organics are taken out by the catalyst or are they on the particles prior to entering the catalyst. The reviewer also asked what enters the environment if a GPF is not used. The reviewer added that the project team should install a TWC and then characterize the PM composition for representative fuels. It is easy and will make a big contribution to public risk.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer stated that GDIs are coming in a big way, fuels may also be changing, and particles are a key concern. The reviewer added that this study provides base understanding.

Reviewer 2:

The reviewer commented that the findings from this study could help GDI engines in meeting future emissions standard. The reviewer added that GDI engines improve fuel economy (FE), which would support DOE objectives of petroleum displacement.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that $200,000 is not much, but the team has delivered. The reviewer added given this and the future plans, resources seem adequate.

Reviewer 2:

The reviewer stated funding seems to be adequate for the remaining tasks.

Cummins SuperTruck Program Technology and System Level Demonstration of Highly Efficient and Clean, Diesel Powered Class 8 Trucks: David Koeberlein (Cummins, Inc.) - ace057

Presenter

David Koeberlein, Cummins, Inc.

Reviewer Sample Size

A total of seven reviewers evaluated this project.

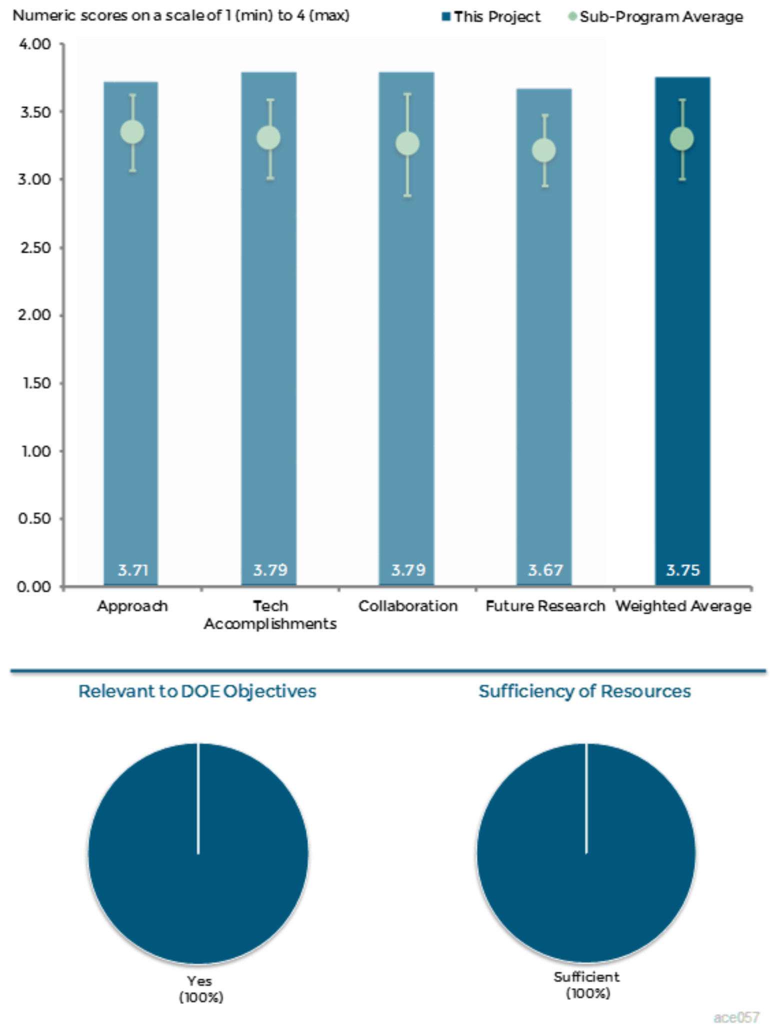

Figure 4-25 Cummins SuperTruck Program Technology and System Level Demonstration of Highly Efficient and Clean, Diesel Powered Class 8 Trucks: David Koeberlein (Cummins, Inc.) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that using dual fuel for commercial vehicles would be extremely challenging because of high load limit even at 40% load as well as super–high hydrocarbon (HC) and carbon monoxide (CO). This would not be a practical approach; however, the reviewer is glad to see that this approach is downgraded and more reliant on the conventional approach. The program provides a parallel approach to minimize the program risk. The reviewer added excellent job.

Reviewer 2:

The reviewer said that this approach was comprehensive and considered all possible sources of fuel economy gain. The reviewer added that the project stayed on plan and was solidly successful. The reviewer also said it resulted in a very good test vehicle.

Reviewer 3:

The reviewer stated that Cummins demonstrated greater than 50% BTE without WHR. This is a tremendous achievement and was only previously possible in large, slow-speed diesel engines.

Reviewer 4:

The reviewer said t ruck and 50% BTE g goals were exceeded, so obviously the approach was successful. Start with analysis, and plug away at easiest then hardest. The reviewer added that in retrospect, 51% BTE could have been achieved without waste heat recovery (WHR) and subsequent vehicle changes. The reviewer stated that for the 55% BTE approach diesel seems better than dual fuel. Excellent refinement and optimization. The reviewer asked with regards to ethanol dual fuel, if petroleum displacement was really better than BTE reduction. The goal changed, and this needs re-evaluation with regards to greenhouse gas (GHG) impact.

Reviewer 5:

The reviewer indicated that the project team had an excellent approach for current period 55% BTE target pathway includes consideration of diesel only approach and dual fuel and utilizes industry state of the art computational fluid dynamics (CFD) analysis coupled with a limited test program.

Reviewer 6:

The reviewer stated that the Cummins team has successfully identified and implemented a combination of technologies that resulted in not only meeting but exceeding the DOE program goals. The project team has successfully demonstrated a greater than 50% brake thermal efficiency (BTE) engine. Additionally, the reviewer said by working with their partners, the project team implemented aerodynamic technologies and rolling resistance reduction technologies in addition to a host of other technologies to be able to exceed the set goal of 50% improvement in freight efficiency. Moreover, the team has identified a technology pathway towards achieving a 55% BTE engine. The reviewer indicated that overall this is a very successful program wherein the technical barriers were addressed early in the program, and a technology pathway was identified to address them; however, considering the fact that this is a 15 minute review wherein the presenter does not share all the details with the review panel, the reviewer believed that Cummins has projected extremely optimistic values in being able to achieve a 55% BTE engine.

Reviewer 7:

The reviewer indicated that this could have been an outstanding rating, but many details were not divulged, and this reviewer is not sure whether it is due to time limitation, or whether there were intellectual property (IP) issues preventing disclosure. For example, the details were missing for the injection rate shaping approach on Slide 14, and the new CFD tool details on Slide 18. Without the details, the approach cannot be judged.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said all are excellent or outstanding. WHR optimization, thermal losses, combustion improvement, analyses. The reviewer added that the truck design seems practical. Impressive engine and vehicle improvements combined to exceed goals.

Reviewer 2:

The reviewer stated all project targets were met, all were delivered on schedule. This was a very impressive accomplishment.

Reviewer 3:

The reviewer stated that there was excellent technical progress in that pathway for 55% BTE is not only being modeled but tested on dyno engines. Base program objectives of 50% BTE contributing to freight efficiency targets completed in previous years. The reviewer added that the data is supportive of progress. Effective engine out emission data and temperatures to meet emission standards would rate in outstanding category.

Reviewer 4:

The reviewer stated that waste heat recovery was taken from a concept to a marketable device which the reviewer is sure the industry will see on future products from both Cummins and other users.

Reviewer 5:

The reviewer remarked that a lot of work has been done with Approach 1 even though Approach 2 is not practical due to dual fuel assumptions. The results do show the possibility to achieve the 55% goal.

Reviewer 6:

The reviewer commented that Cummins has used a combination of technologies to improve engine efficiency: engine down-speed, high conversion efficiency NO_x aftertreatment, and parasitic power reductions. Additionally, the project team has worked with their partners to identify technologies to further improve vehicle efficiency: improved aerodynamics, reduced rolling resistance tires, significant vehicle reduction. The reviewer added that the project team identified a technology pathway in achieving 55% BTE that includes optimized bowl, better fuel injection system, thermal barrier coating, and waste heat recovery. If one were to believe the numbers shown in the presentation, the team has achieved all the major goals of this DOE program.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated that there was excellent collaboration with national laboratories, suppliers, and universities. Dual fuel consortium has potential to be outstanding.

Reviewer 2:

The reviewer remarked that Cummins did an outstanding job coordinating the design and function of engine systems with the cab design and working with their partners to reduce road loads (aerodynamics, rolling resistance) and auxiliary loads.

Reviewer 3:

The reviewer commented that many collaborators and excellent communications and contributions. The project management is outstanding.

Reviewer 4:

The reviewer said it has been great by working with so many partners under this program.

Reviewer 5:

The reviewer stated that there was no evidence that there were problems with any of the suppliers and collaborators. The managerial skills that were required to keep all those suppliers balanced is impressive.

Reviewer 6:

The reviewer indicated that the project has worked with a truck manufacturer, Peterbilt, in addition to having worked with at least eight other Tier-I suppliers. By all means the team has achieved the main goal of this American Recovery and Reinvestment Act (ARRA) program, that of spurring economic activity. The reviewer added that the project team has evaluated ethanol compression ignition (dual fuel activity) with Oak Ridge National Laboratory, which to a large extent has foreseen a technical barrier. An alternate pathway is recommended. The reviewer stated that a better university participation is also recommended.

Reviewer 7:

The reviewer stated that this project benefited from a good team of multi-faceted organizations. Last year's comment still applies in that the presentation does not detail the contributions of all the partners.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer indicated that this project has been completed and closed out. It is a good demonstration of DOE investment into technology development that can contribute and in some cases actually be implemented into production. The reviewer added that the DOE should continue to fund cost-shared projects like this successful one. One aspect of the project, the alternate dual fuel approach, is being continued beyond the SuperTruck program, funded by other sources.

Reviewer 2:
The reviewer noted that if the DOE is considering a follow-up program, continuation of the present effort is highly recommended. This is the only program wherein various candidate technologies are evaluated for potential integration into a future product; however, the DOE should find a pathway to make all the findings from such an effort publicly available.

Reviewer 3:
The reviewer noted that the project is wrapping up in 2015; however, the funding opportunity announcement (FOA) and the effort are models for advancing the industry toward step function real world FE gains in the commercial truck sector. The reviewer added that future possibilities for funding and effort will be high-value proposition approaches for Class 8 trucks from SuperTruck and the next generation Class 8 truck or possibly the next priority in freight fuel consumption.

Reviewer 4:
The reviewer stated that a future project of this magnitude with Cummins would be of solid value.

Reviewer 5:
The reviewer said project complete.

Reviewer 6:
The reviewer said that the program should be finished by now.

Reviewer 7:
The reviewer commented that dual fuel 55% BTE approach seems much riskier and difficult than diesel; however, GHG impact with E85 may be beneficial. Petroleum displacement does not seem to matter much anymore (despite DOE's contention). The reviewer added that going forward, it seems likely that 55% BTE approaches will begin consolidating among program participants. 50% BTE saw different approaches. 55% needs everything.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated absolutely, this project supports the overall DOE objectives of petroleum displacement with significant improvement on both engine and vehicle. The reviewer added that the project is well done.

Reviewer 2:
The reviewer stated that Cummins reached all the goals set by the project.

Reviewer 3:
The reviewer remarked that the super truck goals of 50 BTE were demonstrated and 55% BTE pathway was clearly present options for near term, significant fuel consumption reduction for Class 8 trucks.

Reviewer 4:
The reviewer commented that both the demonstration of efficiency gains and the alternate fuel (petroleum displacement) were in support of DOE goals.

Reviewer 5:
The reviewer stated that in this project Cummins has identified a technical pathway towards substantial efficiency improvement and subsequently implemented and tested engines, and the vehicle as a whole. While this just proves a potential pathway for petroleum use or reduction by trucking industry, it is yet to be implemented into commercial production. The reviewer added that previous experiences elsewhere in DOE programs show that engine companies can demonstrate engine builds with excellent benefits, however, they are very reluctant to introduce any of them into the market citing durability issues and customer preference. The

true objective of the DOE program will be realized when at least some of these efficiency enhancing technologies will find their way into commercial products.

Reviewer 6:

The reviewer said obvious.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the project team accomplished their goal on time.

Reviewer 2:

The reviewer commented that the project budget and cost share contributions were quite significant and benefited from ARRA funds at the outset. The high level of funding generated high expectations, but the project delivered and results lived up to expectations.

SuperTruck Program: Engine Project Review: Sandeep Singh (Detroit Diesel) - ace058

Presenter

Sandeep Singh, Detroit Diesel.

Reviewer Sample Size

A total of seven reviewers evaluated this project.

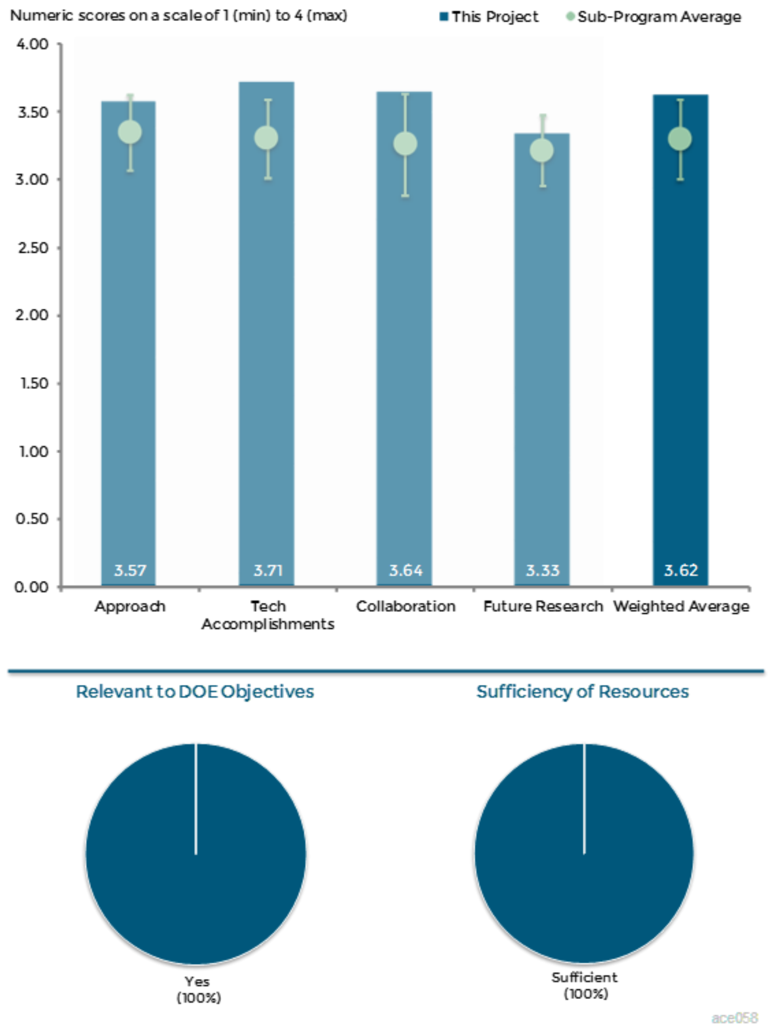

Figure 4-26 SuperTruck Program: Engine Project Review: Sandeep Singh (Detroit Diesel) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that this project, like several other SuperTruck projects, is complete and was a solid success. It used the bit by bit process which characterized all the projects. The reviewer has noted a consistent successful progression of project results based on participating in previous project review cycles.

Reviewer 2:

The reviewer commented that early in the program the Detroit Diesel Corporation (DDC) team identified a technology mix, associated potential barriers and adequately addressed them through a developmental program.

Reviewer 3:

The reviewer indicated that 48% BTE without WHR is a commendable achievement and should be directly applicable to production engines.

Reviewer 4:

The reviewer noted that the project team had an excellent approach to meet program objectives for 50% BTE on a diesel only Class 8 truck.

Reviewer 5:

The reviewer indicated that the project exceeded goals, so excellent approach. 48% BTE on core engine, then WHR addition. The reviewer added that there were lots of optimization and incremental improvements and there were good analyses. For 55% BTE, electronic waste heat recovery (eWHR) feeds well with potential hybridization and solar. Conservative benefits are appropriate. The reviewer added that dual fuel approach with natural gas (NG) seems reasonable, 3.8-5.7% BTE points impressive out of the box; however, the reviewer would prefer to see a more conventional approach.

Reviewer 6:

The reviewer stated that the approach in this project has been to explore all possible pathways for improving the BTE of the ICE. As a result, the goals were all met and nearly all of the barriers were surpassed. The reviewer added that the project is an extremely successful program that is now closed out. The analysis of NO_x aftertreatment operating cost was a good grounding exercise to keep customer acceptance in focus.

Reviewer 7:

The reviewer stated that using 11 liter engine is too risky due to reliability issue. This approach has a little or no chance to be commercialized in 10 years but it does serve the program objective, nicely done. The reviewer added that using dual fuel would not work for commercial vehicle due to high loads. This approach cannot handle the peak cylinder pressure and rise even at 10 bar of brake mean effective pressure (BMEP). In addition, the reviewer noted that the use of NG as an alternative fuel for dual-fuel option would create many issues, such as super-high HC, methane (CH_4), and CO. It is extremely challenging to remove CH_4 under normal temperature. The approach should address this issue.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the project team has a demo truck that is getting significant notice. WHR was evaluated for this vehicle, but not to the sophistication that Cummins has; however, the hallmark of this approach was the predictive engine control. The reviewer believed that was a very solid success and can be or perhaps is already being commercialized.

Reviewer 2:

The reviewer noted that for engine improvement the project team has used a technology mix of WHR, parasitic loss reduction, low-energy intensive aftertreatment system, including various combustion system developments that lead to down-sizing and down-speeding. The reviewer added that vehicle improvements included reduced aerodynamic drag, low-rolling resistance tires, and light-weighting. As a result the project team was able to achieve 50.2% engine BTE, as well as greater than 50% improvement in vehicle fuel efficiency as a whole. The reviewer also stated that between 2014 and 2015 AMR presentations, DDC has shared all of their test results to a large extent to establish some amount of credibility, unlike other awardees. The project team also gives an honest projection of the capabilities of candidate technologies in their ability to help achieve the 55% BTE goal.

Reviewer 3:

The reviewer reported that six BTE points (42 to 48%) showing a variety of approaches. Integrated and done very well. The reviewer added that predictive controls were different and effective; interesting on NO_x and selective catalytic reduction (SCR) temperature. The project team pushed de-NO_x technology. The reviewer stated that for the 55% BTE, Turbo matching and EGR balance was done well and balanced with SCR capability, especially considering CARB directions. The reviewer stated reasonable analyses on dual fuel approach.

Reviewer 4:

The reviewer explained that only a couple of the technical barriers were not overcome, but the project goals were all met or exceeded. The demonstration of petroleum replacement with the dual-fueled NG/diesel pilot was interesting, and an impressive replacement percentage.

Reviewer 5:

The reviewer indicated that even though dual fuel still has a lot of hurdles to overcome, application of this approach to a heavy-duty (HD) engine is encouraging. The reviewer looks forward to seeing the results.

Reviewer 6:

The reviewer stated that the project achieved 50% BTE and have scoped out pathway for 55% with dual fuel approach. For outstanding, clear definition of engine out emissions and engine performance results could be presented.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that a project as complex as this requires major project management skills. Detroit Diesel has consistently employed them to reach their goal. The reviewer believed Kevin Sisken initiated the project and was consistently effective.

Reviewer 2:

The reviewer indicated that there was outstanding collaboration with supplier companies and universities in all aspects including engine, after treatment, hybrid and vehicle systems.

Reviewer 3:

The reviewer commented that this project benefited from a very comprehensive team that was assembled and managed. It was very well coordinated to achieve the program goals.

Reviewer 4:

The reviewer reported that the DDC lists a total of 21 partners in this effort who either as subcontractors or part suppliers have helped the project achieve the program goals; however, primarily, the project team has worked with Oak Ridge National Laboratory (ORNL) in evaluating NG-diesel dual-fuel combination that has shown excellent benefits in terms of efficiency gains. The reviewer said that in fact it is one of the prime candidates in support of achieving 55% BTE engine. Early in the program the team worked with Massachusetts Institute of Technology (MIT) to identify ways to reduce friction at the piston-liner interface.

Reviewer 5:

The reviewer stated that impressive collaborations resulted in different approaches and good results. Model-based control different. The reviewer added that it was nice to see thermal - lube oil work, but much of the collaboration was internal.

Reviewer 6:

The reviewer reported that working with ORNL is encouraging.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that recommending Detroit Diesel for a future program of this scope would be very effective.

Reviewer 2:

The reviewer said there was an excellent approach to future dual fuel work with a national laboratory and supplier community support.

Reviewer 3:

The reviewer reported that it was nice to see a different approach versus Cummins to 55% BTE with dual-fuel approach and more control. Nice analyses on capabilities of conventional combustion. The reviewer was not too concerned about CH_4 emissions, as light-off temperatures are coming down. Proposal needs to contemplate this, given emerging GHG importance.

Reviewer 4:

The reviewer stated that DDC did evaluate WHR thoroughly to give an honest projection of maximum efficiency gain achievable using that technology. As a result DDC projects a technology mix centered around NG-diesel duel fuel mix in order to achieve 55% BTE. The reviewer added that it is highly recommended that DOE follow-up the present program in the future. The industry finds that this is the only effort wherein various technologies are evaluated for potential integration into future products. The reviewer noted that the researchers have been very forthcoming in sharing technical details to provide an honest assessment. This trend should be encouraged in the future.

Reviewer 5:

The reviewer commented that the project has been closed out. Some research will continue from other funding sources beyond this project. The reviewer added that this project was a good demonstration of DOE making a good investment to demonstrate and advance technologies that can be commercialized.

Reviewer 6:

The reviewer said the project was complete.

Reviewer 7:

The reviewer was not quite convinced if the approach is able to achieve 55% goal with dual fuel approach. It would be better if a parallel approach can be proposed in reducing the overall program risk.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said yes, this project supports the overall DOE objectives of petroleum displacement with significant improvement on both the engine and vehicle.

Reviewer 2:

The reviewer stated that SuperTruck goals are clearly tailored to petroleum displacement and this project has exceeded all program goals.

Reviewer 3:

The reviewer indicated that the project met the goals of 50% BTE engine efficiency and demonstrated the pathway to 55% BTE. These will reduce the consumption of petroleum in the United States.

Reviewer 4:

The reviewer stated that over the road Class 8 diesels consume a majority of the petroleum used in the transportation sector. These improvements in fuel consumption will have a significant effect on the bottom line of transportation fuel consumption.

Reviewer 5:

The reviewer indicated that the award to DDC has resulted in an honest assessment of various candidate technologies to result in a technology mix leading to a 50.1% BTE engine. Also, a vehicle with greater than 68% freight fuel efficiency improvement has been demonstrated. The reviewer added that while this is very encouraging, the true benefit of petroleum displacement will only be achieved if some or all of the contributing efficiency enhancement technologies find their way to commercial products. As witnessed in previous DOE funded program, demonstrated engine builds never make it into production. The reviewer said some of the cited reasons being cost, customer acceptance and durability.

Reviewer 6:

The reviewer said obvious.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said the project team successfully completed project.

Reviewer 2:
The reviewer noted that the project was funded at a very generous level (partial ARRA funding), so expectations were high, but achievements did not fall short of expectations.

Reviewer 3:
The reviewer reported that the goals were achieved on budget.

Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer: Russ Zukouski (Navistar International Corporation) - ace059

Presenter

Russ Zukouski, Navistar International Corporation.

Reviewer Sample Size

A total of six reviewers evaluated this project.

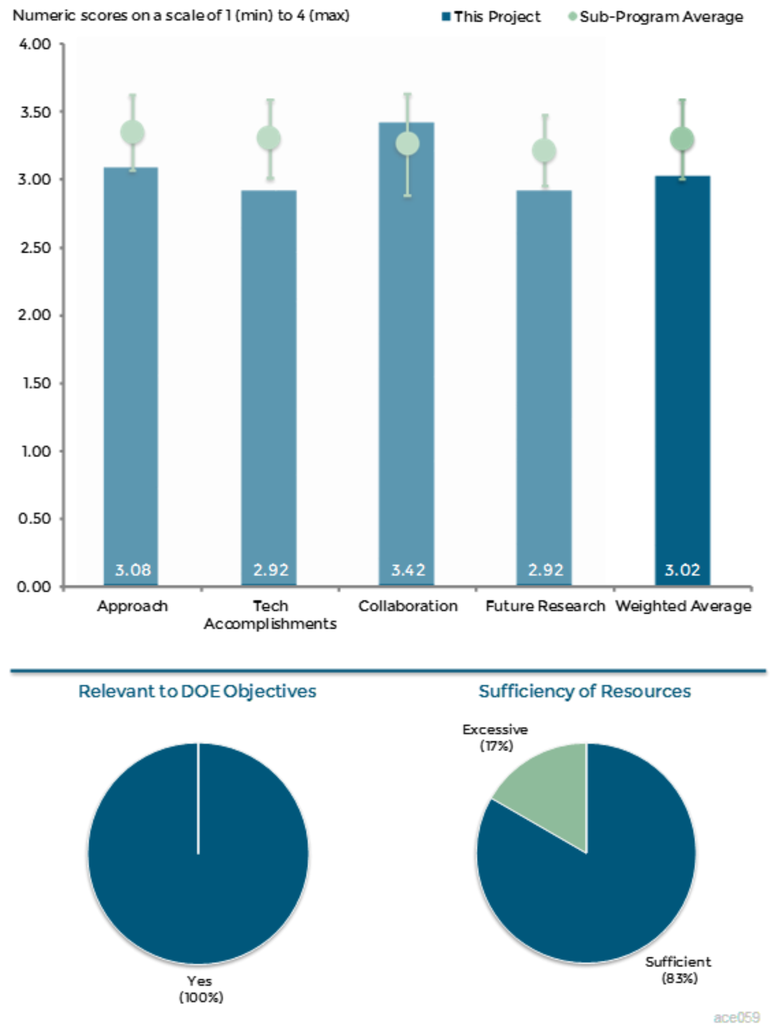

Figure 4-27 Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer: Russ Zukouski (Navistar International Corporation) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that achieving greater than 48% BTE prior to WHR is commendable.

Reviewer 2:

The reviewer indicated that Navistar did an excellent job in developing a program that at the outset clearly identified the goals, and developed a developmental program that also catered to the customer needs. The technology mix identified and pursued towards 50% BTE engine includes down speeding, parasitic loss reduction, advanced combustion development, and gas flow optimization. The reviewer added that the technology mix identified towards 55% BTE system includes organic Rankine cycle ORC, driven turbo as well as some amount of dual-fuel technologies; however, Navistar does not seem to address the third objective altogether, for example, of demonstrating a vehicle with greater than 50% improved fuel efficiency.

Reviewer 3:

The reviewer reported that it was nice to see different approaches from others, variable valve actuation (VVA), parasitic reduction. Nice distribution of BTE impacts over levers with near-equal contributions to 50% BTE. The reviewer would like to see 50% BTE without WHR using driven turbo.

Reviewer 4:

The reviewer said that the project team had a solid approach to achieving SuperTruck goals with building block technologies. Usual suspects have been identified; WHR, advanced combustion, VVA, parasitic reductions and good approach to use CFD plus dyno and leveraging Tier 1 supplier and national laboratory capabilities.

Reviewer 5:

The reviewer stated that it is not clear how an engine can achieve 50% goal without WHR with Rankine cycle. From 48.3 to 50%, mainly relying on the technologies mentioned is not convincing. The reviewer is not sure how down-speed calibration can help this program a lot because the benefits with down-speed can be only seen in an integrated vehicle among engine, transmission and axle. Furthermore, relying on driving turbo (Slide 16) to achieve 50% goal is optimistic, because this driven turbo is more like electric type rather that waste heat turbo-compound that pass the work directly to the engine crankshaft. The reviewer added that the developer should be aware that drawing the energy from the battery to charge the engine would reduce brake-specific fuel consumption (BSFC) as well, and that efforts relying on E-turbo would not be sustainable for a long period of time.

Reviewer 6:

The reviewer indicated that the project scope holds similar elements to the Cummins and Detroit Diesel projects. The reviewer would like to have seen more emphasis on waste heat recovery research. The reviewer expressed disappointment in the delays in the project, and suggested a review of results in relation to other similar successful work.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that there were very impressive parasitic reductions through variety of approaches. VVA work was nice to see, different from others, and helps build to 55% BTE.

Reviewer 2:

The reviewer indicated that excellent progress was reported, and with more detailed data, rating could be improved to excellent or outstanding. Reported to be approaching 50% goal at 48.3% BTE actual. The reviewer reported that the engineering data provided is extremely limited and includes only a few highly diluted plots. Data showing work on diesel engine performance, and engine-out emission data and exhaust temperatures relative to baseline engine could improve rating. The reviewer added that the data provided only for dual fuel engine is not convincingly substantiated for the level of result reported and funding provided.

Reviewer 3:

The reviewer said nothing too different; however a bit more work on the dual fuel without too much is exciting.

Reviewer 4:

The reviewer stated that 48.3% is not too impressive even though the program has been paused for a while, mainly all of its competitors are making striking progress.

Reviewer 5:

The reviewer commented that Navistar did undergo a period to overcome critical company issues wherein the program was paused. After coming out of the pause period, the project team has made a sufficient amount of progress to demonstrate a 48.2% BTE engine through dynamometer tests. The reviewer added that the project team plans to achieve 50% BTE by using an additional driven turbo. The reactivity controlled compression ignition (RCCI) work conducted at ANL demonstrates 45% BTE through the use of a diesel plus gasoline/alcohol mix. While the gains are significant they do not hold promise to be a candidate technology to achieve 55% BTE.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that the project team was excellent using strong Tier 1 suppliers, national laboratories, and universities to meet goals.

Reviewer 2:
The reviewer said very solid, the ANL connection seems quite extensive.

Reviewer 3:
The reviewer stated that as shown in Slide 6, Navistar has worked with various part suppliers including Bosch, Mahle, Borg Warner, etc.. The Project team has exclusively worked with ANL in evaluating RCCI on an engine equipped with VVA.

Reviewer 4:
The reviewer commented that there was broad collaboration with reputable partners. The roles fit nicely into program, but progress from each is unknown. The reviewer added that some sacrifice due to pause is likely inevitable.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the driven turbo approach will be key. The reviewer would like to see 50 BTE without WHR, and characterized this as realistic. The dual fuel approach to 55% BTE is similar to others, but analyses seem to be developing.

Reviewer 2:
The reviewer thought that the approaches taken in ace060 and ace057 show a clear path to 55% or greater BTE without the added complexity or emissions issues associated with dual-fuel combustion. The reviewer would rather see this work redirected towards part-load low-temperature combustion (LTC) or taking further advantage of the VVA system via Miller cycle along with further WHR improvements to achieve 55% BTE.

Reviewer 3:
The reviewer said that there was good proposed future work following building block technologies. Focus should be on data driven approach and data sharing.

Reviewer 4:
The reviewer stated that even after considering the fact that Navistar has been through some rough times, one cannot overlook the fact that Navistar does not have a pathway to demonstrate a vehicle fuel efficiency improvement of 50%. Aerodynamic drag reduction, light-weighting, low rolling resistance tires, etc. as pursued by other teams are important factors towards achieving overall vehicle efficiency improvement, and they cannot be ignored. Also, the reviewer said that the technology mix identified by Navistar towards demonstrating 55% BTE engine is rather weak.

Reviewer 5:
The reviewer warned that completely relying on E-turbo in the future to achieve 50% efficiency is highly risky.

Reviewer 6:
The reviewer said the research plan lacks innovation.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that although the progress is behind their competitors due to pause period, all the work that has done so far would definitely support the overall DOE objectives of petroleum displacement

Reviewer 2:

The reviewer commented that the SuperTruck 50% BTE goal with near-term production technologies and 55% stretch goals will enable significant fuel savings due to the high fuel burn of Class 8 trucks in the medium and HD sector, which accounts for approximately 30% of all transport fuel burned annually.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that the high and sufficient level of funding requires high level of reporting responsibility.

Reviewer 2:

The reviewer stated that there is much work left, but seems well-funded.

Reviewer 3:

The reviewer reported that a total of $35 million out of the promised $39 million has already been allocated by DOE just to see the demonstration of a 48.2% efficient engine. Even looking at the individual technologies in the technology mix, besides driven turbo all others are more or less similar to the ones pursued by other teams. The reviewer is afraid that DOE is getting a miniscule return on investment (ROI) in this project.

Volvo SuperTruck - Powertrain Technologies for Efficiency Improvement: John Gibble (Volvo) - ace060

Presenter

John Gibble, Volvo.

Reviewer Sample Size

A total of eight reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

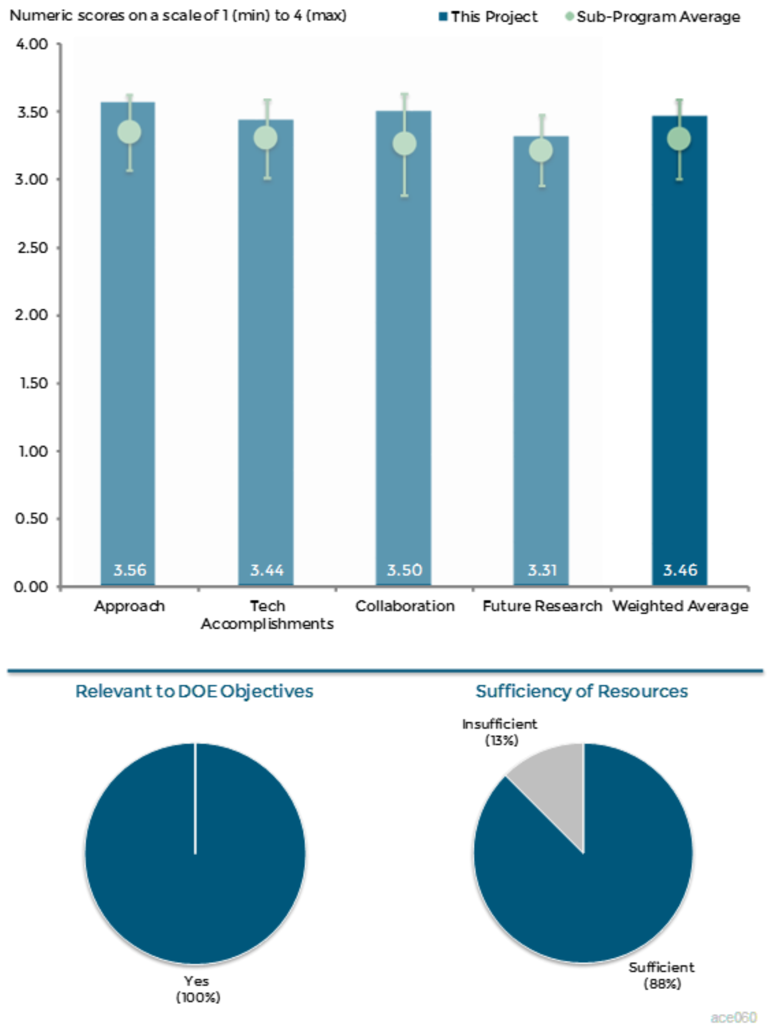

Figure 4-28 Volvo SuperTruck - Powertrain Technologies for Efficiency Improvement: John Gibble (Volvo) – Advanced Combustion Engines

Reviewer 1:

The reviewer commented that as compared to all the awardees under the SuperTruck program, Volvo has identified a logical pathway that establishes technology development goals for 55% BTE engine, 50% freight efficiency vehicle improvement, and a 50% BTE engine. Moreover, each of these three stages feed into each other to identify a logical path. Additionally, the reviewer said that the barriers associated with each stage are adequately identified. This awardee deserves an extra credit in choosing a technology pathway that also accounts for customer requirements, and in being able to deliver a commercial product finally.

Reviewer 2:

The reviewer reported that Volvo achieved greater than 50% BTE without WHR. This is an outstanding accomplishment.

Reviewer 3:

The reviewer stated that the project had an excellent approach to meet SuperTruck 50% thermal efficiency truck-based goal with building blocks of WHR, aftertreatment, down-speeding, downsizing, air handling, pumping work, friction, combustion and current engine level demonstration at 50%. The project is a good pathway for 55% efficiency described is all diesel fuel approach. The reviewer added that a successful diesel-only approach is expected to have lower probability for success than bi-fuel or alternate fuel approaches according to industry experts so has raised some concerns. For excellent rating for 55% pathway and 50% vehicle level performance, detailed sharing of performance, FE, and emission data and assumptions should be provided as well as confirmation that down-speeding and downsizing can in fact perform in time to speed/time to torque as effectively as base comparison engine.

Reviewer 4:
The reviewer said the project had a good mix of technologies to achieve these aggressive goals. There is a logical balance of 50% and 55% engine approaches with good technology transfer and translation between both goal engines.

Reviewer 5:
The reviewer indicated that the project team is doing a good job of catching up on a lower budget.

Reviewer 6:
The reviewer remarked that the approach was outstanding and different to final goal of 55% BTE, starting there and going backwards to build up to final goal. Good start with modeling to guide work. The reviewer added that in regards to 48% BTE without WHR, it was excellent to incorporate durability testing into evaluation.

Reviewer 7:
The reviewer explained that this area could have been explained much better in the presentation, only a general sense of the approach for the various areas was mentioned, making it difficult to evaluate without details. The project conducted a lot of on-the-road testing of major components, which provides a high level of confidence that the final product will be robust. The reviewer added that the WHR expander was coupled to engine directly, which is a novel approach. It seemed that the difficulties associated with that were not mentioned. The reviewer also said a good use of simulation tools was able to make improvements during phase II.

Reviewer 8:
The reviewer commented that it is not clear what assumptions are used to achieve 56.2% goal, specifically using GT-Power. Simulations can provide anything one wants, but under what conditions. The reviewer added that if the entire work is based on simulations, the assumptions must be explained and exposed, this should be part of the program. Using proprietary as a way to avoid the questions and answers are not helpful.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that the progress is good for the current stage of the program. There is still more work to do, but in particular, the 50% BTE goal engine has demonstrated excellent efficiency. Also, the reviewer said that advanced WHR hardware has been designed, built, and demonstrated. The 55% BTE engine concept is in simulation stage but showing predictions to meet the goal (in large part due to extra expansion).

Reviewer 2:
The reviewer said that the second engine build is impressive. New WHR expander very impressive and unique. Good transfer into production and use of developed technology. The reviewer added that there was an impressive modeling and plan to 55% BTE. Head room with single fuel modeling.

Reviewer 3:
The reviewer liked the in-house WHR development. This technology is going to succeed with so many players. The reviewer also likes the rapid propagation of the technology to production. The reviewer was not happy with just modeling to validate the integration.

Reviewer 4:
The reviewer reported that simulations have been completed per the plan. Some down-select of engine design was referred to, but the process for doing this was not given. The reviewer said this would seem to be a major accomplishment.

Reviewer 5:

The reviewer commented that the vehicle at 45% and engine dyno components meet the 50% BTE goal. Verbally described emissions (NO_x, PM) at much reduced engine-out levels with aftertreatment challenge lower exhaust temperatures. The reviewer added that for outstanding results, pathway for 55% efficiency outlined (Parasitic Reduction, Waste Heat Recovery, improved Gas Exchange, Heat Loss Reductions, Combustion Improvements, Over-Expansion) should be detailed to vet assumptions in models and the potential performance/emission impacts. There was excellent activity to internally design a downsized WHR device in house at Volvo, outstanding when data is made available.

Reviewer 6:

The reviewer reported that achieving the 50% goal with all key enabling component is encouraging; however, it is not clear how the simulation can show 56.2% without any experimental tests to back it up. Simulation can be garbage in and garbage out under any unrealistic assumptions. The reviewer added that the details of the assumptions shall be released. The work with new generation of WHR is encouraging, specifically on the turbine expander.

Reviewer 7:

The reviewer stated that from the presentation it is not clear whether funding was partially curtailed, or poor execution by the awardee but the progress made is somewhat less as compared to other awardees. The reviewer's assessment towards the three DOE goals is as follows; 50% BTE engine demo, Awardee has demonstrated a 48% BTE engine. Currently working on WHR system optimization that can potentially enhance future engine BTE. 50% improvement in freight efficiency; Not yet demonstrated. The schedule chosen identifies this deliverable at the end of fiscal year (FY) 2016. Regarding the 55% BTE engine pathway, the reviewer explained that the awardee has identified a path that is not too different from other awardees through a modeling effort with partner universities. The reviewer added that notably two achievements differentiate the present effort from that of other awardees, a five-stage axial expander for WHR, and inclusion of expanded expansion cycles towards achieving 55% BTE.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that there was very impressive collaboration, even with the Swedish government. Nice to see the customer as part of the collaboration. The reviewer added that there was modeling, lighting, and components.

Reviewer 2:

The reviewer said that coordinating all those partners is a solid accomplishment.

Reviewer 3:

The reviewer reported that Volvo lists 11 partners on Slide 19, which also includes 4 universities.

Reviewer 4:

The reviewer noted that the large multinational truck company Volvo/Mack is leveraging well internal inter-divisional resources and component/system suppliers for 50% engine based activity and top list of universities for 55% BTE and modeling/testing including University of Michigan, Penn State, and Drexel University. The team also has fuels and lubes support through a major international fuel supplier.

Reviewer 5:

The reviewer indicated that this project does not have very many partners on the engine efficiency portion. Most partners mentioned were related to vehicle/trailer or full truck demonstration portion of the project, which is not what this reviewer is evaluating. The reviewer added that additional collaborators on the engine efficiency stretch 55% goal could benefit the project.

Reviewer 6:

The reviewer said there was a nice team of collaborators. It would be better if more definition of the role of Penn State University was given. The reviewer said it is not clear how the collaboration on simulation is occurring; so, for next AMR, the reviewer suggested a slide focused on explaining the roles and contributions and collaborations related to Penn State University. Numerous supplier involvement is excellent.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that 55% BTE single fuel approach is excellent. There seems to be room for error. The reviewer added that the project team had an evolutionary approach. The approach seems similar to others, but like to see less emphasis on WHR.

Reviewer 2:

The reviewer noted that the remaining proposed research is to execute project deliverables with an excellent building block plan. It would be outstanding to commit to some of the stretch goal performance testing for 55% BTE.

Reviewer 3:

The reviewer reported that the future research plans were good; however, there was not a lot of detail on the 55% BTE engine hardware plans given.

Reviewer 4:

The reviewer stated that the future work on implementation of new WHR is technically solid, which should help the program to achieve the goal. It is not clear what kinds of tests that are used to support the simulations are developed.

Reviewer 5:

The reviewer said that the future research proposed looks good.

Reviewer 6:

The reviewer asked the project team to please describe “over-expansion” in greater detail.

Reviewer 7:

The reviewer commented that the project team really needs to show the integrated hardware. This sometimes sounds like a part development project.

Reviewer 8:

The reviewer indicated that if Volvo were to stick to the proposed schedule, one’s assessment is that they will be able to deliver a 50% BTE engine; however, the team is likely to fall short in meeting the other two goals, for example, demonstrating a greater than 50% increase in freight efficiency and in identifying a viable pathway towards 55% BTE engine.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that the Class 8 trucks represent the largest fuel consumer in commercial vehicles and commercial vehicles are the second largest consumer of petroleum after passenger cars. Customers of the vehicles also value fuel efficiency as a top driver for purchase. The reviewer added that the technologies for fuel savings implemented will therefore save more fuel per vehicle than any other, and the pull from the market is the strongest in the commercial sector.

Reviewer 2:

The reviewer stated that all of the technologies pursued in the project will decrease petroleum consumption specifically in the HD sector. Furthermore, the technologies are wide ranging and will enable economic benefits to many industry areas from original equipment manufacturers (OEMs) to suppliers. The reviewer added that importantly, the benefits are directly applicable to the transport of goods in the United States; therefore, economic benefits will extend to everyone.

Reviewer 3:

The reviewer indicated that Class 8 improved fuel efficiency will be a major reduction in petroleum consumption.

Reviewer 4:

The reviewer noted that with many advanced technologies developed under this program, which have potential to be used in production, this project support the overall DOE objectives of petroleum displacement.

Reviewer 5:

The reviewer said yes.

Reviewer 6:

The reviewer commented that the pathway for 50% efficiency was proposed.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that it is amazing that Volvo can achieve the same goals as others while the funding is only half of their competitors.

Reviewer 2:

The reviewer stated that it was very impressive to see the progress at reduced money.

Reviewer 3:

The reviewer reported that although the project had a lower funding total than other SuperTruck projects, the work level and progress are geared relevant to the funding.

Reviewer 4:

The reviewer remarked that Volvo has agreed to meet the metrics spelled out for all SuperTruck teams at roughly half the budget.

Reviewer 5:

The reviewer commented that this project seems to be funded at a much lower level than the others.

Reviewer 6:

The reviewer said the project team is making decent progress.

ATP-LD; Cummins Next-Generation Tier 2 Bin 2 Diesel Engine: Michael Ruth (Cummins, Inc.) - ace061

Presenter

Michael Ruth, Cummins, Inc.

Reviewer Sample Size

A total of six reviewers evaluated this project.

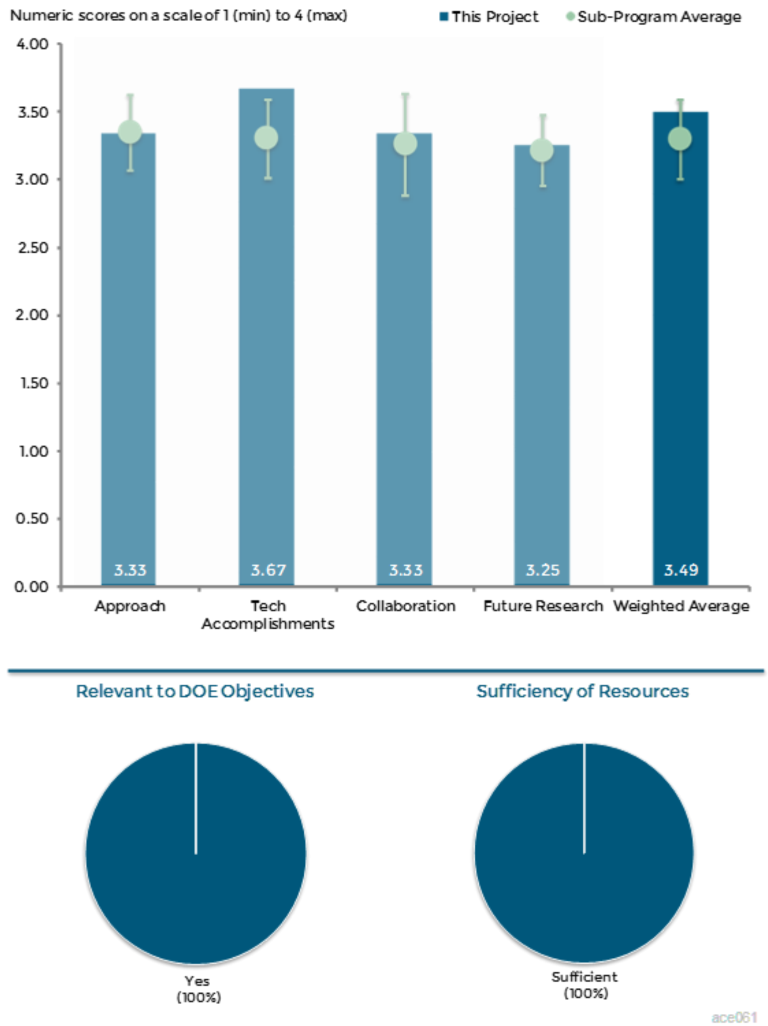

Figure 4-29 ATP-LD; Cummins Next-Generation Tier 2 Bin 2 Diesel Engine: Michael Ruth (Cummins, Inc.) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that this was a tremendous achievement. Having a light-duty (LD) diesel truck capable of Tier 2 Bin 2/Tier 3 Bin 30 emissions would have been impressive on its own merits. The reviewer added that doing so while achieving better FE than comparable current Tier 2 Bin 5 LD diesel trucks makes this project even more impressive.

Reviewer 2:

The reviewer said that the project team had a very sound and comprehensive approach.

Reviewer 3:

The reviewer stated that the approach by Cummins in the engine development to meet Tier 2 Bin 2 standards is highly questionable as the inline four engine development targets do not match the power of the baseline V8. There is a wide gap on the torque and power capabilities from both engines. The reviewer added that on the other hand, the program leverages a strong approach when incorporating an emission control strategy with minimum fuel penalty.

Reviewer 4:

The reviewer stated that the project team had an excellent approach to meet target to achieve 40% FE improvement over gasoline V8 half-ton pickup truck and meet Tier 2 Bin 2 emission requirements by replacing a gasoline engine with smaller diesel and emission control system (ECS) without a weight penalty. Excellent down-sized engine concept has high power density. The reviewer added that the approach could be improved to outstanding by demonstrating diesel which matches base target V8 engine power/acceleration, noise/vibration and by implementing a more production- proven mainstream aftertreatment such as NO_x absorber. Aspects of Cold Start Concept (CSC™) catalyst for cold start have not been implemented due to durability/cost/functionality. The reviewer also said that NO_x and HC mitigation (traps) have not been durably used in production and the NH_3 gas system applied for immediate reductant delivery is a relatively long-term production possibility as significant industry and supplier alignment /standardization would be required.

Reviewer 5:

The reviewer said this is basically an engine/aftertreatment integrate. It can show what can be accomplished with good integration and new aftertreatment technology.

Reviewer 6:

The reviewer stated that there was a good approach to matching or exceeding the torque of base engine and not the power, but this did raise a question of whether the comparison was fair between the 2.8L diesel and much larger V-8 baseline. The reviewer recommended that, even though the project is over, to prove that the overall utility and drivability of the vehicle is maintained by equal torque instead of equal power. Use of novel SCR system added technical value but detracted from perspective of near-term commercialization.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer liked what the project team have accomplished with the aftertreatment. The reviewer said that light-duty diesels can be done in the United States. The cost/weight comparison was well done.

Reviewer 2:

The reviewer commented that this is truly an outstanding showcase of LD diesel combustion control and exhaust emissions control.

Reviewer 3:

The reviewer stated that the program successfully demonstrated Tier 2 Bin 2 emissions compliance on two prototype vehicles. Emissions and fuel consumption are presented on the U.S. Environmental Protection Agency () 75 test, meeting the required standard. The reviewer added that the current presentation includes a comprehensive review of the aftertreatment. The authors also indicate the team attained the weight neutral goal. The reviewer said that the program includes a gaseous NH_3 for NO_x reduction. Discussion on this highlighted that a better choice would have been aqueous NH_3, especially in the incorporation of the cold start concept (dCSC™) element from Johnson Matthey. The program could have been clearer on the engine description such as the capability of the valve train, EGR high and low pressure loops.

Reviewer 4:

The reviewer remarked that the project achieved or exceeded goals in FE and also reached Tier 2/Bin2 emissions levels. The project also achieved weight parity with base engine.

Reviewer 5:

The reviewer reported that the project exceeded the efficiency improvement goals.

Reviewer 6:

The reviewer stated that the project had excellent results meeting FE and emissions. The project could be outstanding with downsized engine meeting or exceeding base engine power and torque; noise, vibration, and harshness (NVH); and a look at value analysis compared to competitive gasoline engine. The reviewer added that a value analysis would include at least a sense check for techno-economic/market assessment for value of FE improvement relative to acceleration and aftertreatment cost penalties. (The reviewer assumed the CSC concept is a higher cost than a three-way catalyst and that acceleration of a lower-powered diesel engine vehicle is slower than that of V8 gasoline.)

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that clearly this is a close industry collaboration. The reviewer is not really sure about the Purdue University connection, but the collaboration has been exceedingly successful. So, in this case it is not the number, but the effectiveness.

Reviewer 2:

The reviewer commented that collaborators have clear and critical roles and that there were no extraneous collaborators for appearance-sake.

Reviewer 3:

The reviewer said that the aftertreatment partners in this project appeared to be vital to the outcome and were good match. The coordination by Cummins was excellent.

Reviewer 4:

The reviewer noted that the team includes critical partners in the aftertreatment (Johnson Matthey), vehicle (Nissan), and academia (Purdue University). The presentation could have provided more detailed information on their contribution.

Reviewer 5:

The reviewer reported that the partnership with Johnson Matthey appears to have been very successful. Integrating low-temperature NO_x adsorption SCRF® was key to achieving exhaust emissions targets.

Reviewer 6:

The reviewer indicated that excellent collaboration including Purdue University, which worked to evaluate valve train timing aspects, and develop aftertreatment technology with Johnson Matthey. Stronger OEM vehicle coordination for a full suite of vehicle metrics such as time to acceleration/torque, NVH and other drivability metrics could make project collaboration outstanding.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the project team is ahead of the timeline. So the future plans are all gravy.

Reviewer 2:

The reviewer reported that this question was not applicable and that the project is completed. However, this project is a good example of the DOE making good investment choices in the research it is funding. The reviewer added that projects like this, which develop technology for the benefit of consumers, should be continued.

Reviewer 3:

The reviewer stated that the project is winding down to completion in 2015. Excellent project and FOA pushes envelope for development of practical FE and emissions technology with a technology agnostic approach. The reviewer added that future FOAs of this type are excellent to speed the tech to market timing of near-term FE technologies and to move the ball for longer term approaches. To be outstanding, future FOAs should include vehicle level or engine level metrics such as power density, acceleration, time to torque, and some indication of production technology readiness for building block technologies (1-3 year, 4-7 year, 10 year potential) and what barriers need to be removed to move up. The reviewer commented that high pot building blocks and barriers may drive other FOAs.

Reviewer 4:

Reviewer 5:

The reviewer stated that the project ended. Press announcements are out on V8 Cummins in Nissan. The reviewer commented that there would have been value-added to say whether findings from the ATLAS project were used in the V8 commercial engine.

Reviewer 6:

The reviewer said that the Project was completed.

Reviewer 7:

The reviewer said that the program is complete.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that this project supported the development of a considerably more efficient engine. Although diesel fuel is higher carbon, overall GHG reduction is still realizable. The reviewer repeated that the impact on DOE's mission would be more obvious if this engine were going to commercial use or that its technology were being adapted to a commercial product.

Reviewer 2:

The reviewer commented LD diesels at a gasoline powertrain price. It will make major inroads.

Reviewer 3:

The reviewer remarked that as proposed, an across the board fleet FE improvement in light trucks and SUVs of 40% could reduce U.S. oil consumption by 1.5 million barrels /day.

Reviewer 4:

The reviewer noted that this project contributes to the DOE mission to reduce petroleum consumption.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said well-funded, partner match, well delivered.

Advanced Gasoline Turbocharged Direct Injection (GTDI) Engine Development: Corey Weaver (Ford Motor Company) - ace065

Presenter

Corey Weaver, Ford Motor Company.

Reviewer Sample Size

A total of five reviewers evaluated this project.

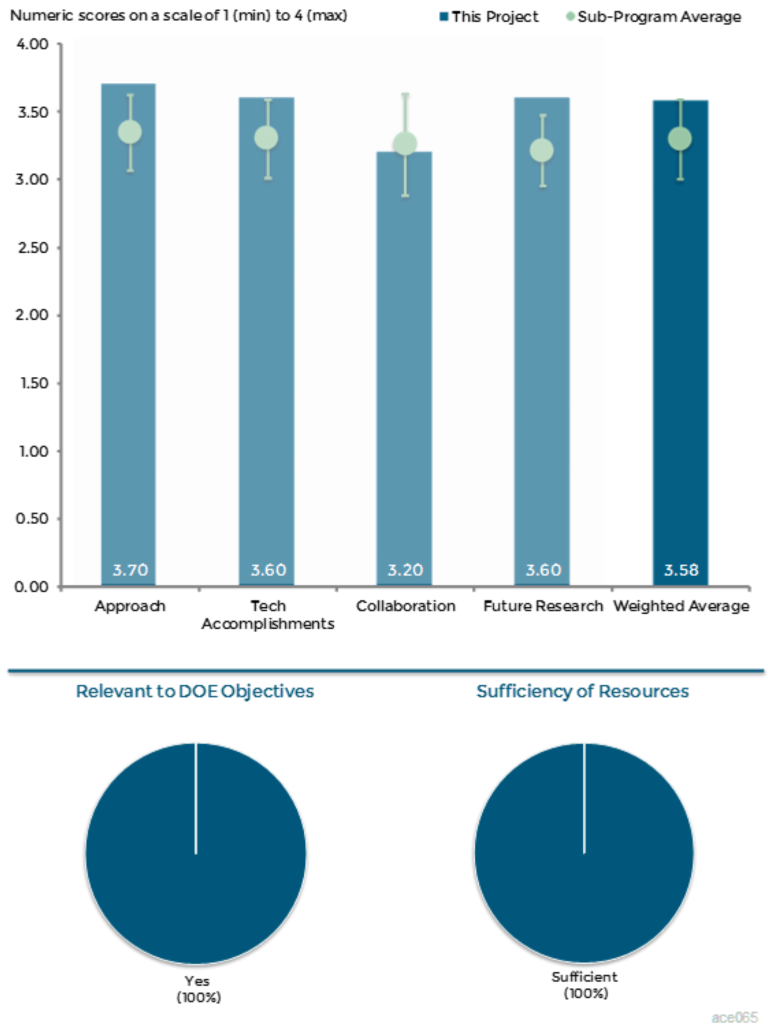

Figure 4-30 Advanced Gasoline Turbocharged Direct Injection (GTDI) Engine Development: Corey Weaver (Ford Motor Company) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that it was a tremendous achievement to obtain a 25% corporate average fuel economy (CAFE) improvement while maintaining stoichiometric 3-way catalytic emissions control and Tier 3 Bin 30 emissions.

Reviewer 2:

The reviewer remarked that the high-compression, dilute combustion strategy is an excellent approach to improving efficiency. It was very well-planned and well-conceived. The reviewer added that this project is nearing its conclusion and has already achieved most of its targets, so the approach was clearly effective.

Reviewer 3:

The reviewer said outstanding and clearly communicated methodology. The project team used engine and vehicle technology elements with high potential for tech to market. The reviewer added that the project has a process following state-of-art vehicle OEM product development cycle from modeling and simulation, product design, on dyno testing with simulation loops, value analysis, vehicle integration and full drivability emissions assessment. Real-world vehicle level metrics clearly defined for fuel economy, emissions, as well as drivability power/acceleration and NVH.

Reviewer 4:

The reviewer noted that this project is a nice example of what it takes to put some advanced engine efficiency technologies through an OEM design cycle to get them close to production. The approach is not overly aggressive compared to other DOE-funded projects, but perhaps this gives the technology a better chance to go into production. The reviewer had some difficulty differentiating this project from the technology already included in the production EcoBoost engine from Ford. From that perspective, it would have been nice to use a production EcoBoost as the baseline engine for this project; however, the use of external cooled EGR is noteworthy as a technology that was included for efficiency.

Reviewer 5:

The reviewer commented that the Ford team has not achieved the performance targets by a combination of engine downsizing, and a host of other technologies while staying with the traditional boosted stoichiometric engine with high EGR and three-way catalyst. The other technologies listed in the AMR presentation are all advanced without giving all the details. The reviewer added that the fact that the project team has developed an engine with research octane number (RON) 98 as the fuel specification allows the team to claim higher efficiencies; however, this is not very practical.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer reported that the project team set out what it intended to do. From the number of engines, vehicles, and operating hours involved, it is obvious that the robustness of this technology was a central consideration. The reviewer added that this will allow Ford to make production-relevant decisions about the technologies included, which supports DOE's goal of accelerating high efficiency technologies into the marketplace. The project was aiming for definitive answers about the technology rather than just check-the-box measures of progress.

Reviewer 2:

The reviewer said outstanding delivery of committed DOE and other vehicle level metrics. The project goals for FE and emissions exceeded DOE goals. The reviewer added that the vehicle meets industry required production acceleration drivability metrics and demonstrated in prototype vehicles with packaging that is near term production plausible. Downsized engine design meets or exceeds time to torque (acceleration) targets established by baseline engine and packages inside production vehicle platform. Also, the reviewer said that high granularity of data demonstrates significant effort following established product development for production pathways. Fully integrated potentially near term production vehicle hardware package delivered that exceeds DOE FE and emission targets augmented by solid effort to move the ball toward future FE gains through R&D on stretch technologies such as lean burn injection, combustion, and advanced ignition hardware and strategies as well as advanced aftertreatment, including passive NH_3 generation for SCR.

Reviewer 3:

The reviewer indicated that the engine dyno results are quite impressive. The project team has done a lot of very good work. The reviewer added that there appears to be a very good chance of meeting the final vehicle efficiency targets at the conclusion of the project.

Reviewer 4:

The reviewer commented that all goals appear to have been met over the course of this project. The reviewer thought it would have been helpful to show results on both 95 RON fuel as well as the 98 RON fuel used because 95 RON is actually available in the United States, even if this meant the loss of several percent relative to the FE target.

Reviewer 5:

The reviewer stated that from the presentation made at AMR one gathers that Ford has achieved, and in some cases surpassed, the DOE goals; however, it remains to be seen as to how many of the technologies developed here will transition to the market.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that there was excellent collaboration with supplier companies as well as Michigan Technological University to deliver stretch goals. Possible inclusion of an advanced aftertreatment supplier to move the ball further on stretch technologies would make this outstanding.

Reviewer 2:
The reviewer stated that Ford has collaborated with Michigan Technical University to evaluate various ignition system variants. Many of the findings are perceived to have transitioned into the final engine developed.

Reviewer 3:
The reviewer commented that there is only one collaboration partner, which is a university subcontractor that appears to have a relatively minor role in the project. It is not surprising that an OEM would prefer to keep most of an engine development program in-house, however, and the reviewer would consider this satisfactory.

Reviewer 4:
The reviewer stated that there is only one partner on this project, so there are not many collaborations; however, as this is a project led by an OEM with a vehicle demonstration, the number of outside collaborations does not need to be large to achieve the project goals.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the Ford team has exhibited exceptional project planning and execution.

Reviewer 2:
The reviewer remarked that this was an excellent FOA and the results with the project wrapping up in 2015. Ford's approach on this project, the level of data, and the results for this FOA is are a good case study. The reviewer added that the approach applies building block technologies, vetted with value analysis, and applied through a clear pathway toward plausible integrated vehicle level approach to meet FE target that have potential for production pathways near-term as main pathway, while also moving the ball on other promising technologies that are possibilities for future fuel efficiency improvement. FOA technology agnostic approach is excellent, and typically used industry vehicle metrics shown in Ford's data, such as time to acceleration, noise vibration, and idle quality, is outstanding.

Reviewer 3:
The reviewer said that the project is reaching its conclusion, and the path to completing the remainder of the work is straightforward.

Reviewer 4:
The reviewer reported that the chassis dynamometer testing appears to be the sole remaining task.

Reviewer 5:
The reviewer indicated that this project is wrapping up, so future work is not really applicable in the context of this project. The reviewer hopes to see this technology in the marketplace.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer indicated that the Ford team has successfully developed a highly efficient engine, integrated into a midsize sedan and finally evaluated the performance of the vehicle to demonstrate, achieving DOE goals. For example, a 25% reduction in fuel consumption while meeting emissions standards.

Reviewer 2:

The reviewer commented that the development of production plausible near-term vehicle technologies integrated on a production vehicle to achieve over 25% FE improvement on midsize sedan has high potential to significantly reduce vehicle petroleum use.

Reviewer 3:

The reviewer stated that efficiency improvements of the scale demonstrated in this project will have a significant impact on vehicle fuel use once the technology reaches the market. Some of the efficiency gains would be contingent on availability of high-octane fuel, for example, renewable super premium.

Reviewer 4:

The reviewer reported that this is highly relevant as it is bringing high EGR dilution technology closer to production, providing a very real efficiency benefit. While the baseline engine could have been a smaller displacement and the technology targets could have been more aggressive, the technology developed will inform production decisions in a shorter-term way than many DOE-funded projects.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that while this project appears to be coming to an end, it was able to achieve the 25% FE targets for advanced dilute combustion without going into exotic combustion/controls (GCI, lean burn, etc.) and thus had a far simpler task achieving Tier 3/Level III emissions. This was a very successful approach. The reviewer would like to see additional developmental work on this platform to see its capabilities on fuels more representative of current U.S. gasolines, for example, 91 RON and 95 RON.

Reviewer 2:

The reviewer noted that the large project budget has been judiciously used and effectively matched.

Reviewer 3:

The reviewer stated that the project appeared to be on-schedule after a delay early in the project, and not in need of additional resources.

Advancements in Fuel Spray and Combustion Modeling with High Performance Computing Resources: Sibendu Som (Argonne National Laboratory) - ace075

Presenter

Sibendu Som, Argonne National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

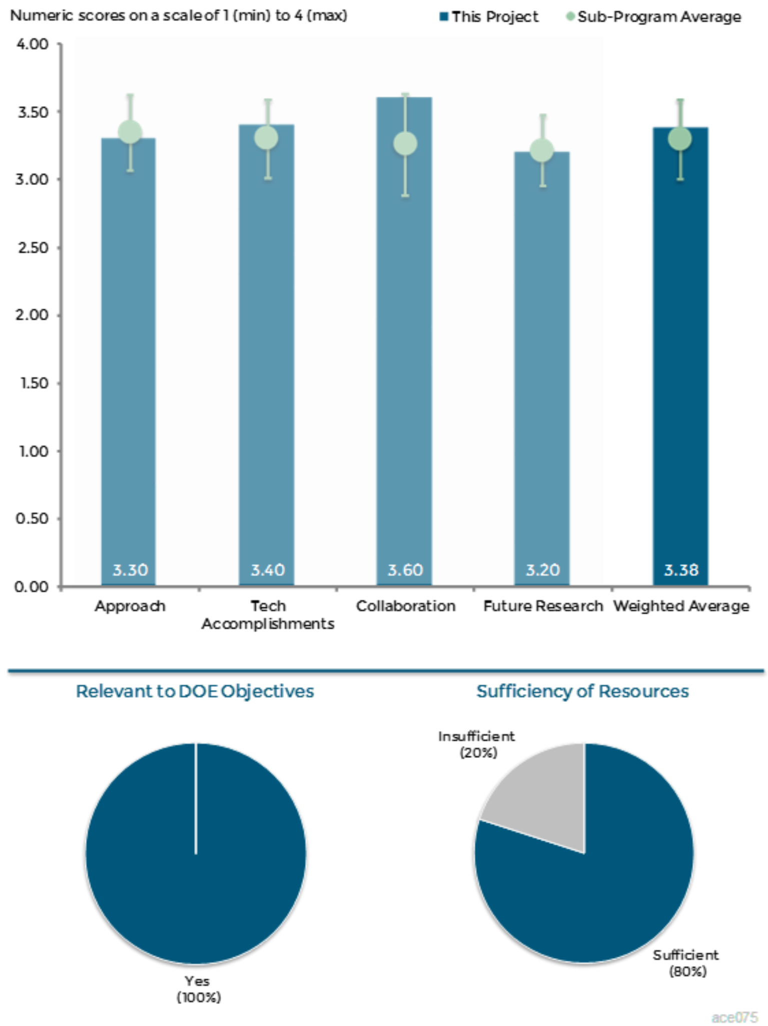

Figure 4-31 Advancements in Fuel Spray and Combustion Modeling with High Performance Computing Resources: Sibendu Som (Argonne National Laboratory) – Advanced Combustion Engines

Reviewer 1:

The reviewer stated that the approach of developing models and comparing results to production injectors is very good. Results of approaches used in this work appear to have convinced an equipment/engine manufacturer to use these techniques.

Reviewer 2:

The reviewer reported that undoubtedly this project is one of the leading efforts on detailed spray modeling and injector flow modeling, and coupling those two processes. Being able to simulate needle wobble and probabilistic nature of shot to shot variation due to that is novel. The reviewer added that for the supplier to be able to incorporate such simulation in their design improvement is encouraging. There was some attempt to explain the workflow but, in the future, dedicating a slide or two in collaboration with the supplier to map out the process of tangible impact on hardware design would be interesting if presented.

Reviewer 3:

The reviewer commented that the work provides a good approach seeking to minimize manual tuning of models to experimental data, promoting more predictive simulations with higher fidelity models. The work focuses on detailed chemistry combustion models, finer mesh for grid-convergence, high-fidelity large eddy simulation (LES) turbulence models, and two-phase physics-based fuel spray and nozzle-flow models. This is combined with high-performance computing facilities.

Reviewer 4:

The reviewer said that this is an excellent project with an excellent approach including attempts to validate key portions of the computational framework. One area where the approach might be improved would be to present more realistic impacts of nozzle back pressure on wobble and cavitation. The reviewer added that it is recognized that the experimental facility at the Advanced Photon Source might have an operational limit, but this is an important topic that needs further investigation as relevant to direct injection (DI) diesel engines.

Reviewer 5:

The reviewer was not sure if high performance computing can really have any impact on reducing petroleum usage in the near-term horizon. Only sample demonstration calculations each of which takes 3-4 weeks to complete and cost on the order of a million dollars can be done. The reviewer added that it cannot be considered as a tool today to design tomorrow's engines. Maybe the engines of the day after tomorrow.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer remarked that this project consistently shows annual progress. Improvements in the ability to do high-fidelity models with high resolution, detailed chemistry, two-phase injection modeling with turbulence is definitely commendable. The reviewer added that the challenge is computing time even with super computers. The reviewer asked how do suppliers' engineering teams incorporate these methodologies. Also, a comparison of good calibrated low-fidelity models with high fidelity models and validation data would provide some insight into how much of this effort is necessary.

Reviewer 2:

The reviewer stated that the PI and team have made outstanding progress in the last year addressing wobble effects and in integrating injector nozzle boundary conditions onto the chemically reactive flow calculations.

Reviewer 3:

The reviewer stated that the significant accomplishments were made, which include: first-ever simulations of a production injector with full needle dynamics (with wobble), which showed that there is significant shot-to-shot differences in wobble, but does not affect global mass flow rates, surprisingly cavitation can occur at low lifts even when it does not occur at high lifts; demonstrated high-fidelity LES approach to capture dribbled mass from a single hole injector.

Reviewer 4:

The reviewer commented that progress on calculations with the LES model, dribble, etc. are commendable; however, more gasoline sprays should be modelled.

Reviewer 5:

The reviewer indicated that the work is technically sound. It covers a very comprehensive sub-model development. Overall the activities are focused. The reviewer added that the work on injector simulation with full needle dynamics is very descriptive. The work provides information of the injection event at low needle lifts where variability is more pronounced. The reviewer also stated that the wobble discussion was very informative. On Slide 8 there is some details on the needle motion. The authors may want to provide a fuller account in order to appreciate the nature of the phenomena described here. For example, the reviewer inquired about the following: the full lift of the needle; the diametrical clearances and tolerance in the injector; and what is used in the model. Similarly, the authors may indicate what the minimum dribble target is. The reviewer additionally said that the team has begun to work on optimized reduced mechanisms for a diesel surrogate. This is being applied to LES modeling. Initial results show increased resolution that manifests multiple ignition sources. The reviewer said that the authors also showed how LES was able to capture dribble mass. These efforts have not been applied to engine simulations yet. The reviewer recommended applying them to selective engine cases to assess its significance in the context of emissions and FE. It is unclear now what such massive effort in the computational area will yield in real life operation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that collaboration with other labs, the Engine Combustion Network (ECN), universities, suppliers, and an OEM is excellent. If this research and fundamental understanding can be considered pre-competitive, which the reviewer thought it was, then why not bring more or all of the fuel injector suppliers to the cooperative research & development agreement (CRADA) tables for improving the success of these methodologies in fundamental understanding and hardware design improvements. The reviewer added that it also appears that a commercial CFD vendor working with high end researchers is a good way to develop and disseminate this development to a wider community.

Reviewer 2:
The reviewer said very good team.

Reviewer 3:
The reviewer commented that there was very close collaboration with two equipment/engine manufacturers and with a simulation development company, as well as with two universities and several other national laboratories.

Reviewer 4:
The reviewer reported that this project includes collaboration with various industry partners, some universities, and another government agency.

Reviewer 5:
The reviewer stated that more collaboration can be pursued with suppliers of gasoline fuel injectors for LD automotive applications.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the future work is certainly well planned. This project makes step improvements every year. The reviewer had no doubts about the success towards FY 2015 milestones.

Reviewer 2:
The reviewer reported that the U.S. automotive LD fleet consists of 96-97% gasoline engines. The portfolio of work should be adjusted so more gasoline sprays and combustion are being modeled if one hopes to impact petroleum consumption of the LD fleet.

Reviewer 3:
The reviewer reported that planned work should continue progress made and move further toward meeting program objectives. Good to see more work on gasoline.

Reviewer 4:
The reviewer stated that the proposed future research was clearly indicated. This includes one way coupling: transitioning to Lagrangian parcels at the nozzle exit, and 2-way coupling; and transitioning to Lagrangian parcels downstream of the nozzle exit. The reviewer indicated that the authors are planning to report on the influence of conicity and hydro-grinding on combustion and emissions behavior. The work with extend gasoline injectors. The project team will continue to improve scalability of engine codes and better and more representative chemical kinetic models. The reviewer wished to emphasize the importance of evaluating the simulation work in real engine applications to demonstrate the applicability and predictability of the models.

Reviewer 5:

The reviewer commented that it would be helpful if future work also included further exploration of nozzle back pressure effects on cavitation and wobble along with further validation of the dodecane mechanism at lower bulk temperatures and various injection pressures. Also, the reviewer asked how this overall effort compares with LES work at Sandia National Laboratories (SNL). The reviewer also asked is there overlap or duplication. This is not clear.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer noted that the project provides fundamental physical understanding of injector behavior and sprays crucial for ICE efficiency.

Reviewer 2:

The reviewer commented that this project should eventually provide engine designers a tool to aid in the development of next generation low emission and high efficiency engines.

Reviewer 3:

The reviewer stated that development of more accurate fuel spray and combustion models coupled with high performance computing will enhance the capability to more quickly design and commercialize advanced combustion engines will reduce fuel consumption and thus reduce amount of petroleum used.

Reviewer 4:

The reviewer reported that the injection characterization work is necessary for improving combustion modeling. This particular project is tied to other current programs. The reviewer added that any progress made here will be applicable across a wide horizon.

Reviewer 5:

The reviewer said that high-performance computing is a long-term play. It is out of the reach of the automotive industry presently.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the project could benefit from additional resources to conduct experimental investigations of injectors at more realistic nozzle back pressures and also further validate the dodecane model at wider range boundary conditions.

Improved Solvers for Advanced Engine Combustion Simulation: Matthew McNenly (Lawrence Livermore National Laboratory) - ace076

Presenter

Matthew McNenly, Lawrence Livermore National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

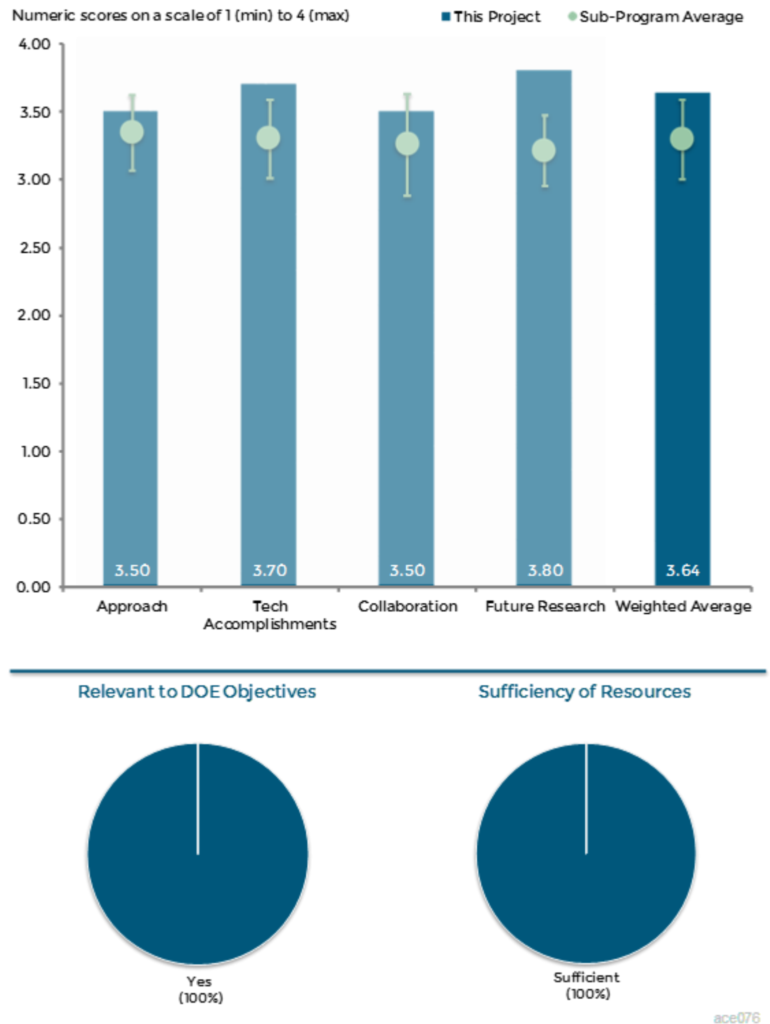

Figure 4-32 Improved Solvers for Advanced Engine Combustion Simulation: Matthew McNenly (Lawrence Livermore National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that this is an exceptional program that addresses a real need; faster and more accurate chemistry calculations for multidimensional engine simulations. The bottom-up approach of attacking the computational approaches for these calculations (versus reducing mechanisms, etc.) is sound and the gains are substantial.

Reviewer 2:

The reviewer reported that the speedup work for chemistry solvers is critical; the approach to investigating how to implement the speedup for a wide range of use cases is valuable. This project is an enabler for the closer-to-the-metal projects as it is still in the development phase and not yet distributed to end-users.

Reviewer 3:

The reviewer said the project is creating faster, more accurate combustion solvers.

Reviewer 4:

The reviewer stated that this project concerns developing a capability for detailed in-cylinder predictions of engine performance, a goal shared by a number of project teams. The PI notes the lack of basic knowledge of engine combustion regimes, modeling capabilities and means to control engine performance. In response, the PI has formed a team of several industrials, national laboratories and universities to address this problem. The reviewer added that the need for a predictive simulation is of course important. There are a number of groups in academia and national laboratories pursuing the same goals. Interestingly, the PI himself seems to be pursuing similar goals in another project (ace012 with almost the same group of PIs; and a few slides seemed to be the same for the two presentations) that is evidently dealing more with combustion chemistry. The broad objectives of this project are to speed up the simulation process by developing faster predictive engine models and to use detailed chemistry in the simulations. Also, the reviewer said that this project should be better differentiated from ace012, as both have the same PIs, similar objectives and funding levels that total about $1 million ($0.5 million for each). The reviewer asked why this project could not be folded into ace012 (or vice versa). The reviewer added that the choice of fuel systems should be clarified. The reviewer asked why a nine-component surrogate (AVFL18) is selected. The rationale here is not clear.

Reviewer 5:

The reviewer suggested that the project team may want to explicitly state the differences between this project and Russel Whiteside's project (ace012).

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said that by all indications there was a substantial improvement in performance.

Reviewer 2:

The reviewer stated that the demonstrated speedups are quite good, and the findings of problems in the thermo property fits are highly valuable in recognizing challenges with running simulations. Uncovering further limitations in high speed/high fidelity computations is of value too.

Reviewer 3:

The reviewer noted that the accomplishments and progress have been good, but the team is challenged to move into other aspects of the multidimensional engine simulation problem to advance all of the elements to make the entire engine simulation process faster.

Reviewer 4:

The reviewer indicated that the idea of using a kinetic scheme that involves 10,000 species and 75,000 reactions would, in some quarters, be considered a bit of overkill. The project should incorporate some sort of rationale for reducing the number of steps, for example by the diagnosis-related group (DRG) method (or some other approach) because it is unlikely that all 75,000 reactions in a scheme will be important. The project does not appear to consider strategies for chemistry reduction. The reviewer added that the computational times noted for the codes evaluated – 90 years for KIVA and open foam, 150 days for commercial solves using sparse systems – seems connected to the use a 52,000 reaction scheme (and therefore 52,000 species diffusion equations that need to be solved simultaneously). Again, such a computational burden is precisely why chemistry reduction is so important. The reviewer stated that the surrogate components listed on Slides 13 and 19 include a list of species was not clear. Some of the species are gas under standard conditions and some are condensed phase. The reviewer said that surrogates for transportation fuels are going to be mixtures of liquids. Please clarify what is meant by the gas species and that the percentages do not add to 100%. The reviewer added that the project focuses on Converge, as does ace012. The reviewer asked if it would it be possible to incorporate the same solver in KIVA or Raptor. The reviewer also asked what the commercial chemistry solver referred to was. The LLNL model was verified against some basic configurations including a counter flow flame, RCM and SCE tests, which is good.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the coordination with the leading engine software vendor is outstanding, but a broader base touching more tools (KIVA, etc.) and even vendors (CD-adapco, ANSYS, etc.) is encouraged. Of course, this is limited by the willingness of these other toolmakers to get engaged, but this reviewer has no doubt that more progress and greater efforts to make this work known to the modeling community will generate such interest.

Reviewer 2:

The reviewer indicated that the integration and beta testing in converge is very good. More direct interaction with the industry players to help them integrate these tools into their work processes should be pursued as well. The reviewer added that the project team further demonstrated code integrations would also be valuable both to increase the reach of the work and to uncover other problems in codes as the additional integrations are worked on.

Reviewer 3:

The reviewer said that a long list of collaborators is indicated. It was not clear in some cases what the collaborators provided or what the PI provided them. For example, nine academic partners are listed. The reviewer asked what these partners will provide. The reviewer also asked how collaboration is coordinated with them. Additionally, the reviewer expressed a need to know if the collaborators received some funding from this project and what Bosch provides, etc., and suggested that more details showing the substance of the collaborations would be beneficial.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that there is a good set of plans that directly feed into broad distribution of the tools and which also progressively attack the various weaknesses in the current simulation tools.

Reviewer 2:

The reviewer commented that the proposed expansion to spray dynamics, etc. is welcomed and timely.

Reviewer 3:

The reviewer noted that a capability for spray dynamics is an area that needs further work for computation. The reviewer then asked does the PI have any insights on what his efforts can contribute to simulating sprays. Some of the future work involves further development of advection algorithms and a website to assist with modifying combustion chemistry, this is good. The reviewer added that in performance of an engine, one can envision that a coupling of the internal fluid/transport/reaction dynamics with materials integrity issues is essential for an accurate predictive capability. This project seems not to deal with the conjugate gas/solid interactions that address this concern. The reviewer said the operation at peak engine efficiency, with operational conditions identified by, for example, the outcome of the PI's simulation efforts, could conceivably impose conditions that the materials could not withstand. Materials stress and fracture dynamics are intimately tied to temperature, which is an output of the present simulations; however, the boundaries of the solution domain consist of real materials with finite limits on their integrity. Also the reviewer said it is strongly recommended, going forward, that the PI begin to think about how his efforts can fold into the simulation of engine performance the materials stress issues that can be important for engine durability.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer stated that higher speed and fidelity simulation tools are a key need for enabling continuing development of high efficiency engines.

Reviewer 2:

The reviewer reported that if one believes that better simulations leads to better engine designs which are more efficient (reducing petroleum consumption), then being able to do those simulations faster will speed the process even further.

Reviewer 3:

The reviewer commented that this project is relevant to the DOE's interests because it seeks to develop the ingredients to an efficient predictive capability for an internal combustion engine.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that expanding resources through CRADAs and other collaborative projects is encouraged.

Reviewer 2:

The reviewer stated that there appears to be a good rate of progress that is in line with the funding amount. It is not clear that more funding would substantially increase the work rate.

Reviewer 3:

The reviewer stated that the budget seems sufficient; when viewed in the context of complementary projects for example, ace012, it begs the question of why ace012 and ace076 are distinct or could not be folded together into one larger effort. Also, the reviewer said that some further discussion would be useful of how the costs are (broadly) divided among the project team.

Cummins/ORNL-FEERC Combustion CRADA: Characterization and Reduction of Combustion Variations: Bill Partridge (Oak Ridge National Laboratory) - ace077

Presenter

Bill Partridge, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

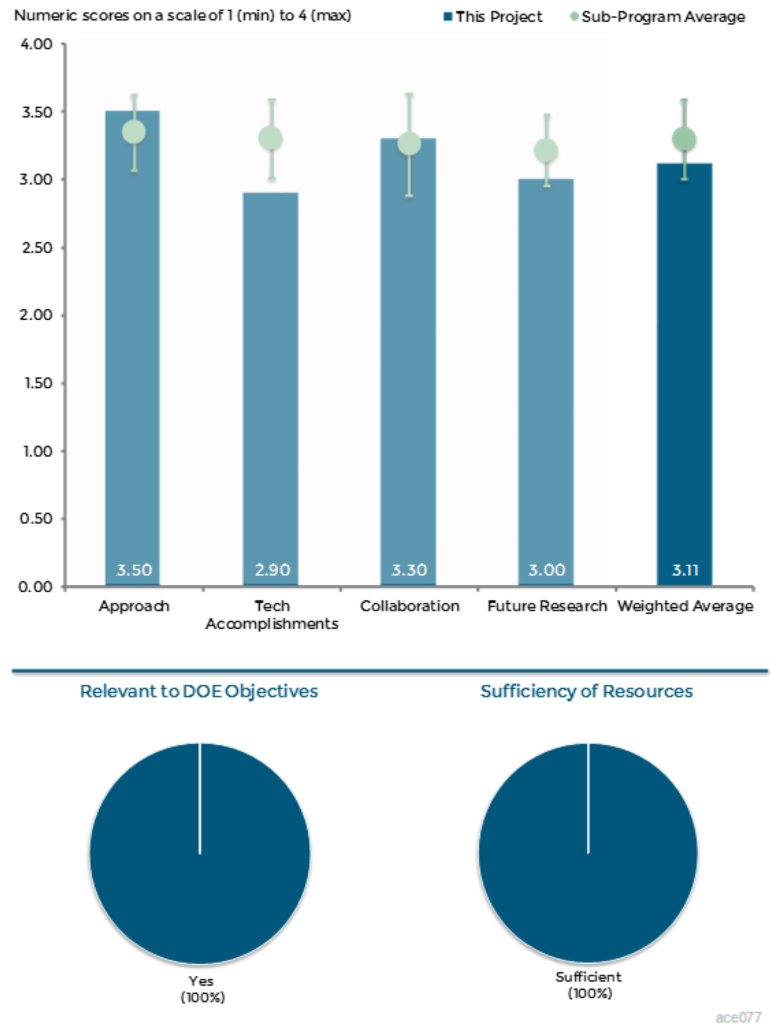

Figure 4-33 Cummins/ORNL-FEERC Combustion CRADA: Characterization and Reduction of Combustion Variations: Bill Partridge (Oak Ridge National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work–the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the work in this project has done some very good work in developing diagnostic tools which enhance our understanding of engine physics, and also make use of them in very practical ways that can be tied into real product improvements. This is a great example of DOE funding positively impacting products that are going to market.

Reviewer 2:

The reviewer stated that the approach for conceiving and then developing the prototype probe has been excellent. The combination of experimental measurements and CFD for the valve overlap period was very insightful for sorting out the capability of the probe to discern external EGR versus trapped residuals.

Reviewer 3:

The reviewer commented that the project seeks to assess fluctuations in cylinder-charge and apply remedies in hardware and control strategies. The results will be improved combustion uniformity and implementation of advanced combustion strategies.

Reviewer 4:

The reviewer explained that this project, which began in 2013, concerns a range of tasks that include developing diagnostics to resolve in-cylinder thermal/fluid processes. A CRADA has been developed with Cummins to collaborate on the work and technology transfer. The reviewer stated that the approach has apparently been to develop a diagnostic to assess in-cylinder flow and thermal uniformity and to apply it to assess specific hardware architectures and acquire data to tune and improve simulation tools. The problem with this presentation may have been that the PI seemed to assume that the audience was quite familiar with the project and the approach, for example, for CFD precisely what code was used was unclear, et etc. c.); however, for some not familiar with the project it came across as rather like a kitchen sink approach to address a plethora of issues the quantifiable connection of which to engine efficiency and FE was in some cases hard to see. The reviewer added that the project includes a lot of tasks and subtasks associated with combustion uniformity, engine controls, diagnostic development, modeling, emissions characterization, durability and detailed modeling. Much seemed to revolve around, or rely on, the efficacy of a laser problem developed previously to provide data that would meet the PI's objectives. The reviewer also said that one of the figures had an arrow of the various components of the project that point to an engine, apparently on the understanding that somehow, what comes out of the subtasks, for example, hardware, systems control, diagnostics development, engine proof, etc., would lead to a clean, fuel-efficient, durable engine in the marketplace. This is unclear. Project management should do more than make broad links to efficiency. The reviewer pointed out that the presentation noted the relevance of in-cylinder charge uniformity that in turn impacts combustion uniformity. It was not clear how a probe positioned at just one location in the combustion environment could assess the extent to which uniformity of anything could be assessed.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that the findings on the backflow versus cool EGR are very interesting, and were well explained to make sense of the flows in the engine. The tool was used in a number of interesting and practical ways to evaluate the flow and EGR distribution in the engine. The reviewer added that this is a key enabler for improving engine designs and ultimately higher efficiency engines.

Reviewer 2:

The reviewer commented that the presented results for the EGR probe were very impressive to date and its ability to estimate residual mass fraction and EGR rate. The only suggestion is to include any cylinder-to-cylinder variation data along with any validation data for the probe's 10% uncertainty capability.

Reviewer 3:

The reviewer stated that the probe is effective in estimating the exhaust gases moving upstream of the intake port during the engine valve overlap. This can be used to estimate the EGR breakdown between internal and external EGR. The reviewer added that some questions arise on the uncertainty evaluation of the measurements. The authors verbally did not seem to be concerned by the uncertainty of the measurements, for example, benchmarking the optical technique with gas analyzers) and were unable to explain the translation of the percent CO_2 concentration to actual mass of flow estimation (the event is highly transient). The reviewer also said both of these issues are a concern for evaluating the technology and should be addressed by the authors with more rigor.

Reviewer 4:

The reviewer pointed out that a laser probe was used to analyze in-cylinder charge components, modifying the probe to resolve backflow measurements, measuring emissions as a function of crank angle, and assess advanced in take architectures (vague, because architectures was not clear) among other things. The reviewer commented that a large part of the presentation seemed to involve tasks associated with using this probe (indeed, much seemed to rest on this probe meeting some project goals). The capability to measure CO_2 and water (H_2O), along with temperature and pressure for the in-cylinder environment would, of course, be good. The reviewer indicated that there are two issues that are raised by this probe development effort. First, the probe appears to provide data at just one fixed location in the intake runner. The reviewer asked if this is this a problem. One of the little images of the intake runner shown in Slide 10 seems to suggest some spatial distribution in the intake runner space. Unless the PIs choose the right location to mount the probe, the results could change and might affect the data. The reviewer added that there does not seem to be a capability to map out the emissions or thermal field in the cylinder, which would be very useful information.

Secondly, the reviewer said the probe does not appear to be especially small, or at the least no information was provide on the potential for the probe itself to influence the flow pattern in the intake runner environment by the physical volume it occupies. It would be useful to provide some measurements of the flow field around the probe to establish that the probe itself is not effecting the distribution of gas species or the temperature field, as it was unclear if its physical presence displaces gas that could affect the flow pattern. Thirdly, the reviewer asked if the authors have considered nonintrusive diagnostics. SNL (Livermore) has some capabilities, and perhaps even ORNL. If so, it would be valuable to compare, say, probe temperatures with similar measured by non-intrusive means. The reviewer stated that some modeling work was presented to predict the evolution of CO_2. The presentation noted 3D-CFD model results. No details were provided. The reviewer stated that more information on the modeling effort should be provided. Making in-cylinder predictions is not well established (other VTO projects are developing detailed simulation capabilities), and the inputs to the codes have a strong effect on the predictions, for example, combustion chemistry of surrogates for gasoline or diesel, thermal physical properties, etc.. Also, the codes need to be validated before they are used. These are not trivial considerations.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that the partnership with Cummins has been very good and there is clear tie-in between ORNL and Cummins. The reviewer would like to see even more expansion of the outcomes of this program into other DOE lab programs; ANL and ORNL engine work could make use of the project results quite effectively.

Reviewer 2:

The reviewer pointed out that this work within the CRADA appears to be quite well coordinated with the key industry partner and a couple other research organizations. It might strengthen the project to include other engine OEMs.

Reviewer 3:

The reviewer stated that this project is a CRADA with Cummins and it is interfacing with the Cummins SuperTruck program. The project team is very accomplished and well known. The reviewer added that it was sometimes a bit unclear how specific results from one part (for example, ORNL) would be used by the other (Cummins).

Reviewer 4:

The reviewer stated that the work presented is practical and valuable. It is an example of a well-run CRADA. The work studied back-flow measurements via a multi-color EGR probe.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that much of the proposed work is refining the tool. This is a good goal and important work, but the reviewer would like to see more development of new tools as part of the CRADA as well. Some of the stretch goal ideas could be pulled forward into the prime path of the project usefully.

Reviewer 2:

The reviewer pointed out that the future work is indicated. It would be important to develop approaches on how to use the information provided to limit the variability on flow. The reviewer added that it will be important to understand how this variability influences or deteriorates engine efficiency.

Reviewer 3:
The reviewer stated that the proposed research is reasonable for further developing the EGR probe. It would be helpful to include cylinder-to-cylinder variation in future work, too for assessing each cylinder's contribution to PM and NO_x.

Reviewer 4:
The reviewer commented that the future work was framed in terms of considerations of what would be needed to improve performance of the probe (improve signal-to-noise ratio, apply it to various engine platforms), develop new data for parameters relevant to engine uniformity, measurement campaigns at CTC for hardware and system control, compare results. The reviewer asked comparing the results of what. The reviewer asked what these models are for the model-based expectations. The reviewer asked what develop stretch technologies means. The reviewer asked what will be done with the data for mass flux and cylinder head temperature. These were somewhat vague.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that this work promotes useful techniques and instrumentation to better understand and benchmark engine performance.

Reviewer 2:
The reviewer noted that this project indirectly supports DOE goals by providing engine OEMs a diagnostic to develop improved air systems toward reducing emissions in future engines. Also, the probe might be able to aid in better transient EGR control strategy development as one looks into the future.

Reviewer 3:
The reviewer indicated that there is key linkage between the project and the goals to reduce petroleum use. Cummins has clearly demonstrated good tech transfer from DOE to their work, and others likely are as well.

Reviewer 4:
The reviewer commented that the capability to monitor internal flow processes is important for improving performance of the ICE. The matter here is if the probe used in this study is the best instrument for that purpose. The reviewer stated that given that it, apparently, cannot provide spatially resolved measurements, a high reliance on identifying the most suitable location for data extractions is needed. This consideration could limit its usefulness. The reviewer added that nonintrusive diagnostics are important though difficult to apply.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that the funding level appears to be good; the reviewer is fairly certain that some more progress could be made with additional funding though.

Reviewer 2:
The reviewer stated that for what is included in this project, it is a relative bargain at $250,000 per year. Other projects that, for example, deal with only computational efforts have budgets in excess of double this project, which includes tasks associated with both experiments and modeling.

Investigation of Mixed Oxide Catalysts for NO Oxidation: Janos Szanyi (Pacific Northwest National Laboratory) - ace078

Presenter

Janos Szanyi, Pacific Northwest National Laboratory.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

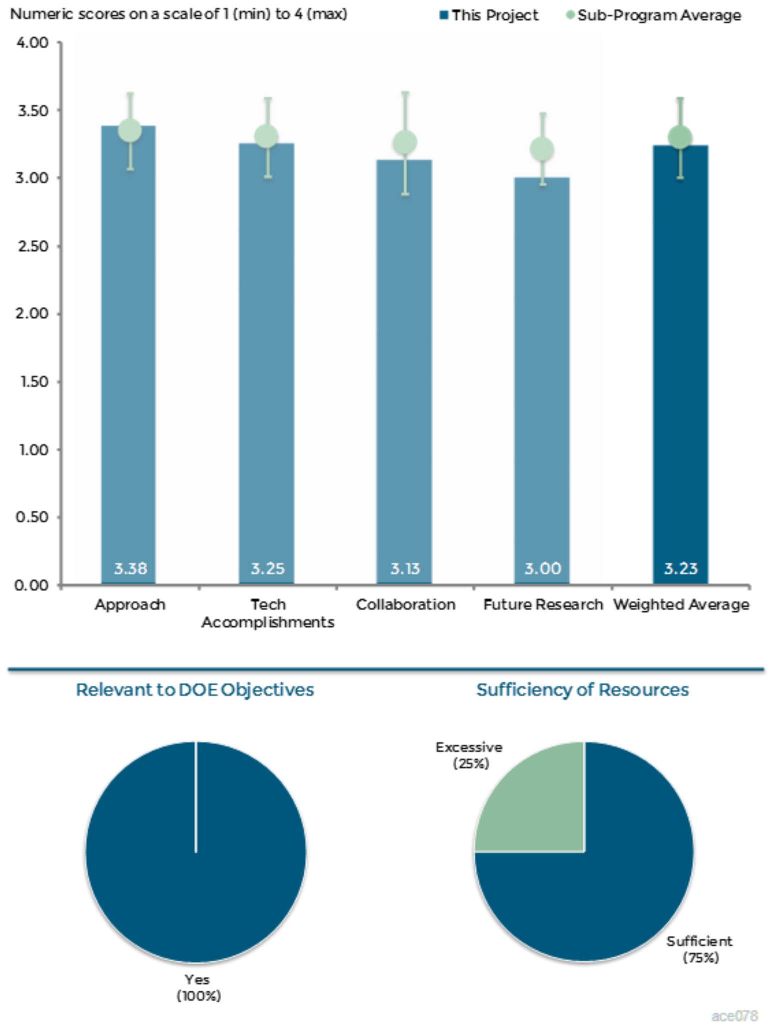

Figure 4-34 Investigation of Mixed Oxide Catalysts for NO Oxidation: Janos Szanyi (Pacific Northwest National Laboratory) – Advanced Combustion Engines

Reviewer 1:

The reviewer stated that the approach of using a bank of methods to characterize these catalysts was very effective.

Reviewer 2:

The reviewer commented that the project team had an excellent approach to develop advanced catalyst formulations to evaluate both fresh and lab-aged catalyst materials to optimize the formulations for diesel oxidation catalyst (DOC) and lean NO_x trap (LNT) applications considering low-temperature catalyst light-off performance targets and using materials other than the platinum metal group (PGM).

Reviewer 3:

The reviewer pointed out that a strong and scientific approach was taken to understand the manganese dioxide (MnO_2)-Cerium oxide (CeO_2) system for nitrogen oxide (NO) oxidation. The isotope labeling studies were very effective for probing the lability of the oxygen on the catalyst. The reviewer added that the $M2O_2$ loading studies were effective for determining the portion of MnO_2 that is effective for NO oxidation. The different synthesis methods were good for investigating whether a mixed oxide of ceria and manganese was necessary or could the simpler process of post-impregnating manganese on ceria result in a catalyst that was effective for NO oxidation. The reviewer stated that the combination of reactor studies, density functional theory (DFT) calculations, catalyst synthesis methods, and Fourier transform infrared spectroscopy (FTIR) methods demonstrated a strong and effective scientific approach to catalyst development.

Reviewer 4:

The reviewer explained that investigating lanthanum perovskites and MnO_2 in such detail, when both are known to have severe sulfur poisoning issues, is not a great starting point. Even if either had a 50/50 chance of solving the problem, the combined probability would be less than 15%. The reviewer said it is just not a great starting point, no evidence of success was shown.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer remarked that the project team had excellent progress applying catalysis expertise, state -of-the-art analytical techniques, computational analysis to investigate surface and bulk properties of the catalyst materials with respect to changes in composition and interaction between reactants and the potential active sites while supporting very promising manganese oxide (MnO_x)/CeO_2 formulations with 50-60% NO oxidation light-off performance at 200°C and very limited hydrothermal aging impacts. Although surface area measurements show 30-40% loss due to aging, aging has little effect on catalyst activity. The reviewer added that the project team did excellent work to incorporate zirconium dioxide (ZrO_2) into MnO_x-CeO_2 mixed oxide showing increased catalyst activity, improved hydrothermal aging, and increased sulfur tolerance with 70% of the conversion restored by a rich treatment.

Reviewer 2:

The reviewer stated that there was a great accomplishment for using the labeling studies to demonstrate the stronger lability of the oxygen on the manganese/ceria catalyst relative to that of ceria alone. The loading study work clearly showed that it is the surface manganese that is effective for NO oxidation. The reviewer added that a particularly good accomplishment was showing that the simpler process of impregnating manganese on ceria produced a catalyst that was as effective for NO oxidation as a catalyst prepared by the more complicated approach of doping manganese within the ceria matrix. Another accomplishment was the incorporation of zirconia into the formulation to improve its thermal stability; however, a much greater investigation into the effects of thermal aging, sulfur poisoning, and desulfation characteristics needs to be demonstrated. The reviewer warned that without thermal durability and an effective desulfation process, the catalyst could never be used on a vehicle.

Reviewer 3:

The reviewer commented that the project team did nice work on the surface analysis. It does provide guidance for future work on other systems. The reviewer added that DFT was mentioned, but few results were shown.

Reviewer 4:

The reviewer commented that the increased understanding of MnO_2 and its interaction with ceria has come from this work. More work with sulfur tolerance is needed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said excellent CRADA partnership with GM, PNNL and Tianjin University.

Reviewer 2:

The reviewer said that this project was basically a three institution effort, with no other collaborators, so it could have somewhat broader in the efforts by the PNNL partners, particularly in China.

Reviewer 3:

The reviewer commented that there was clearly a good division of effort between PNNL and GM, where GM focused on the catalyst formulations and reactor testing and PNNL focused on catalyst characterization and synthesis methods.

Reviewer 4:

The reviewer reported that GM apparently was a major initial partner, but they were not included in the report. The DFT was apparently done at a university in China, but was only verbally acknowledged.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that the research is complete for this excellent case study CRADA. Future similar activities to reduce or optimize aftertreatment (LNT, DOC, diesel particulate filer [DPF]) catalyst PGM usage, develop low-temperature aftertreatment oxidation catalysts and better characterize active site micro-structure in oxidation catalyst to effectively model and design productive future catalysts using small focused working group is strong recommendation for future work.

Reviewer 2:

The reviewer recommends that the work continue with an emphasis on improving the thermal durability and the desulfation capability of the catalyst.

Reviewer 3:

The reviewer stated that the contract is over, so there will be no more work in this specific project.

Reviewer 4:

The reviewer said not relevant; better initial thought on the project would be preferred.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer stated that advanced aftertreatment with reduced or eliminated PGM materials resulting in lower cost aftertreatment solutions and lower temperature performance can enable the use of advanced combustion strategies in a production environment.

Reviewer 2:

The reviewer pointed out that such a catalyst could allow lean operation on gasoline or diesel applications while allowing a reduced cost aftertreatment system to achieve strict emission standards.

Reviewer 3:

The reviewer commented that replacing platinum (Pt) would help in accomplishing better FE.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said excellent result and use of budget.

Reviewer 2:

The reviewer commented that the project goals appeared to be satisfied and that the project is discontinued.

Robust Nitrogen Oxide/Ammonia Sensors for Vehicle On-board Emissions Control: Rangachary Mukundan (Los Alamos National Laboratory) - ace079

Presenter

Rangachary Mukundan, Los Alamos National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

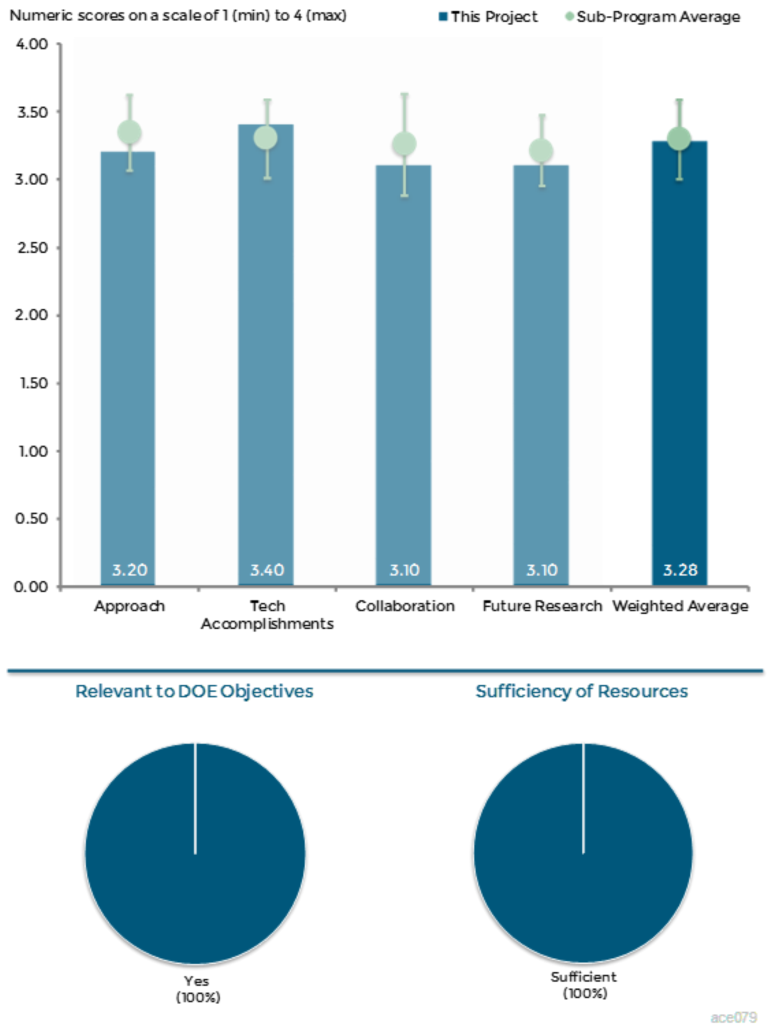

Figure 4-35 Robust Nitrogen Oxide/Ammonia Sensors for Vehicle On-board Emissions Control: Rangachary Mukundan (Los Alamos National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that there was an excellent collaborative approach adopted to overcome the technical barriers. The adopted approach seeks to solve key issues to commercialize low cost NO_x sensors for vehicle applications.

Reviewer 2:

The reviewer said the project seems to be well connected with current sensor manufacturer and well aware of what is needed for commercialization.

Reviewer 3:

The reviewer said that this project is well thought out and technically sound. Even though it is set out to overcome the barriers mainly in NO_x measurement. The reviewer added that the potential of the sensor could also measure NH_3 and HC is very beneficial in the future. At the same time, the sensitivity of the sensor in measuring NO_x seems to be influenced by many factors. The project is still quite a distance away from the target of plus/minus five parts per million (ppm) or better.

Reviewer 4:

The reviewer pointed out that NO_x sensors that meet stringent vehicle requirements are available and are on every post-2010 medium- and HD diesel and every post-2008 LD diesel sold in the United States. While the reviewer understands the need for improved NH_3 sensing, it is difficult to understand the manner in which the nearly ubiquitous position of NGK as an original equipment zirconia-NO_x sensor supplier for the past 5-7 years was completely ignored when setting project goals. The reviewer asked how is this approach fundamentally better than what is currently in use by engine and vehicle manufacturers.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer reported that significant progress has been made with sensor related development. The project is on track against milestones. Letters of Interest from a variety of OEMs, Tier 1 suppliers and sensor development companies show general acceptance of the sensor concept. The reviewer added that input from a broad range of stakeholders would be valuable and helps to the move the sensor toward commercial use.

Reviewer 2:

The reviewer stated that this project has already achieved 85% of its goal towards developing robust NO_x sensors for vehicle on-board diagnosis and control. Investigators have successfully carried out engine evaluations and sensor packaging studies. The reviewer added that this is significant progress towards a commerciality viable sensor for on-board diagnostics (OBD) applications.

Reviewer 3:

The reviewer remarked that there was surprisingly good NH_3 selectivity.

Reviewer 4:

The reviewer stated that this project is actually fascinating work. Very competent in the work being done.

Reviewer 5:

The reviewer commented that it is not clear how the cross sensitivity to HC will be solved to make the sensor useful to measure NO_x and NH_3.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that collaboration and coordination with universities, industry partners, and national laboratories has been excellent. The efforts in seeking commercialization has been fruitful.

Reviewer 2:

The reviewer stated that there was excellent collaboration with laboratory, university, and vendor participation with a Tier I/OEM partner identified for further development.

Reviewer 3:

The reviewer said that steps toward commercialization are very important.

Reviewer 4:

The reviewer commented that having a close partnership with a major sensor supplier (Bosch, NGK, Denso, and Delphi) will be critical to proceeding into later stages of development and will be absolutely necessary for commercialization.

Reviewer 5:

The reviewer noted that the project is very well tied to the organizations that matter for this project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that this type of project is really well aligned with the car/engine manufacturers need to satisfy the emission controls. Much work in the SCR field today is about discerning the difference between NO_x and NH_3. The reviewer added that this sensor should eliminate the ambiguity.

Reviewer 2:

The reviewer commented that the proposed future work is reasonable. Given the fact only a few months are left for the project, focus should be placed on improving the sensor sensitivity.

Reviewer 3:

The reviewer commented that future work is focused more towards sensor tolerance towards impurities and real driving situations. A major portion of this work is to commercialize the sensor technology for closed loop control, which may take time.

Reviewer 4:

The reviewer observed that it will be crucial to improve the accuracy of the sensor and figure out how to eliminate or work around the HC cross sensitivity.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer stated solving emission controls allows OEMs to push engine out up, ensuring more efficiency but, still be compliant.

Reviewer 2:

The reviewer said that if successful, the technology would results in fuel saving that would support DOE objectives of petroleum displacement.

Reviewer 3:

The reviewer stated indirectly, as goals are more focused on the emissions control problem, but as emissions control and FE get interrelated in the engine design process, success here will ultimately aid building better engines which consume less petroleum.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the project was done on time and within budget, must be good.

Reviewer 2:

The reviewer noted that that funding seems to be adequate for the remaining tasks.

Reviewer 3:

The reviewer stated that resources seem adequate.

High Efficiency GDI Engine Research, with Emphasis on Ignition Systems: Thomas Wallner (Argonne National Laboratory) - ace084

Presenter

Thomas Wallner, Argonne National Laboratory.

Reviewer Sample Size

A total of six reviewers evaluated this project.

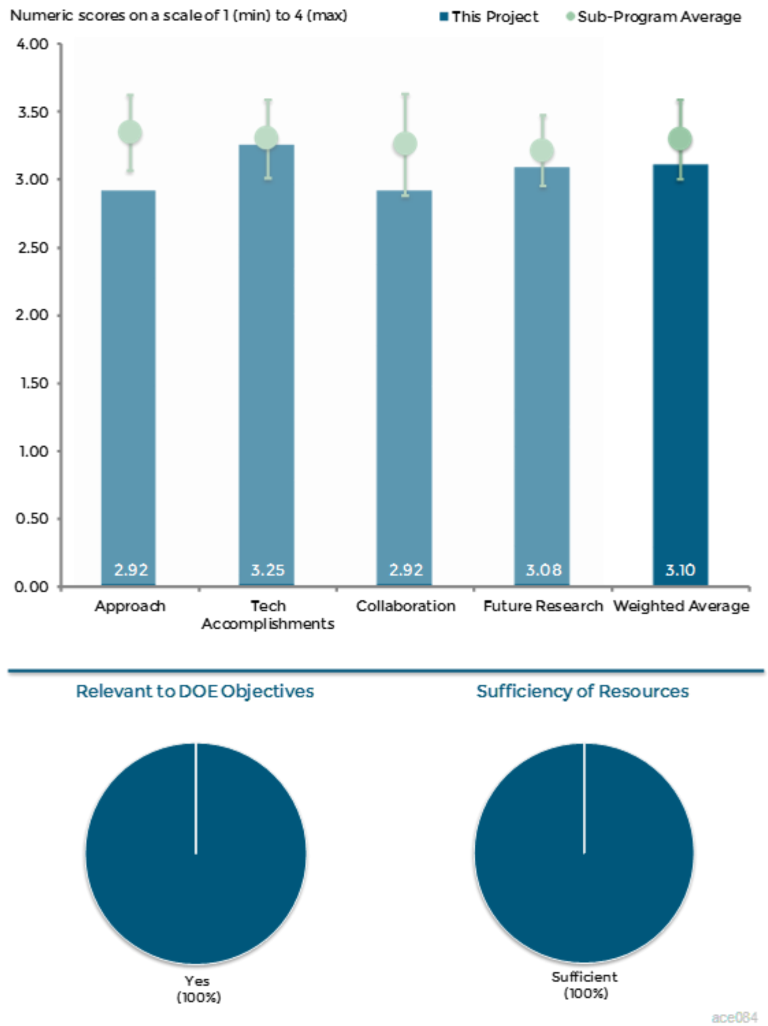

Figure 4-36 High Efficiency GDI Engine Research, with Emphasis on Ignition Systems: Thomas Wallner (Argonne National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer explained that the study focusses on dilute gasoline combustion, a combustion pathway on the U.S. Driving Research and Innovation for Vehicle Efficiency and Energy sustainability (U.S. DRIVE) Advanced Combustion and Emissions Control ACEC Roadmap, which is commended.

Reviewer 2:

The reviewer pointed out that the overall approach has been excellent to date including both experimental and analytical approaches. The only suggestion the reviewer has is to explore other potential important engine operating conditions to assess the various ignition systems.

Reviewer 3:

The reviewer remarked that the approach is very solid. The project seeks to overcome the barriers to robust lean-burn and EGR-diluted combustion technology and controls. The reviewer added that the area is relevant to boosted and down-sized engines. The work looks to ignition systems (solid state lasers) and their potential use with lean/dilute combustion. Finally, work focuses on development of modeling tools. The reviewer also said the work is relevant as dilute spark ignition (SI) combustion offers the great potential for decreasing fuel consumption. The authors present Honda's valuable and recent reference, indicative of the current standard.

Reviewer 4:

The reviewer observed that the goal of increasing the dilution limit for lean and high-EGR engines is valuable, but the industry has already done a great deal of work in this area in the pursuit of these combustion systems. Laser ignition has been investigated for decades now, and many of the plasma/corona systems have been developed to near-production readiness by the Tier 1 suppliers. The reviewer added that the additional evaluations by DOE seems to be somewhat duplicative of work that is already being done. The modeling tool evaluation/development to capture the stochastic nature of high dilution combustion is valuable and should be a long-term investment in enabling better dilute engines.

Reviewer 5:

The reviewer commented that the approach was assessing the compatibility of advanced ignition systems with lean or dilute combustion systems, developing modelling tools to rapidly screen new designs, and studying combustion stability issues seems appropriate.

Reviewer 6:

The reviewer commented that the conventional coil ignition may not be the best baseline. The reviewer understood that it is readily available, but it is important to be able to compare to spark plug based systems with improved coils that ignition system manufacturers are working on. These are the systems that are relevant as a comparison.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer listed the good progress including establishing the minimum number of cycles required for stability assessment, demonstrating that Reynolds-averaged Navier Stokes (RANS) can be used as a tool for combustion stability assessment, and experimentally showing that lean cases are more sensitive to perturbation than baseline and EGR dilute cases.

Reviewer 2:

The reviewer observed that the authors have made good progress in this calendar year across a range of tasks and the work is well documented. The author's study of stability addresses first the use of a statistical evaluation of multi-cycle experimental data to establish a minimum cycle number for stability. Secondly, the work evaluated stability through perturbation of ignition energy and timing. The reviewer added that this is a good lead in to the simulation validation, which established RANS as a tool for combustion stability assessment. The study shows the effect of the variability of the in-cylinder flow from cycle-to-cycle and correlates it to the experimental engine data. The reviewer commented that it appears that the variability introduced is limited to the flow variability. The reviewer suggested that the authors comment on why the variability is limited to flow and not include the fuel quantity or ignition variability. Overall, the results do show that the multi-cycle RANS modeling correlated to experimental data at least qualitatively. The authors compared the RANS performance with LES, indicating that LES provides only minor improvements. The reviewer added that with regards to extending the operation regime of EGR dilution, the work has yielded limited success. The authors completed installation of a laser ignition through spark-plug geometry. The reviewer pointed out that tests were carried out to understand the impact of multi-pulse operation and separation between pulses. Results indicate limited impact. The reviewer commented that the level of laser energy was also reported and overall indicated that it does not significantly improve dilution tolerance either. Tumble ratio did not affect stability either tough influenced other combustion metrics. Additionally, the reviewer said that the interaction between ignition and flow were simulated with emphasis on multi-point laser ignitions. These later results suggested improved efficiency and reduction of variability. The reviewer also stated that the later ignition system characterization included a non-equilibrium plasma system. These results indicate improvement of dilution tolerance, significantly better than the conventional spark.

Reviewer 3:

The reviewer commented that the RANS modeling results were interesting, as was the comparison with the LES models. It is somewhat odd that LES predicts such high cycle-to-cycle variability (CCV) for non-dilute operation while predicting relatively accurate CCV for dilute. That suggested to the reviewer that the model is not predictive at all really. The reviewer added that the three-point laser ignition result was interesting. If there is going to be work on laser ignition, it should be on ideas like this that could show some improvement and which may be different from the long history of laser ignition research.

Reviewer 4:

The reviewer stated that the laser results are interesting but do not suggest that laser ignition will ever be better than electrical systems. The reviewer added that a key question for a laser based system is how to keep the access window clean.

Reviewer 5:

The reviewer commented that this project has derived new insight on CCV from a simulation perspective that could useful outside the context of this particular project. Work during the past year has been insightful for assessing laser ignition and one plasma approach and their ability to extend the EGR limit at one key engine operating condition.

Reviewer 6:

The reviewer reported that it is concerning to see sporadic misfires in some of the data shown. Either the misfires should be included as part of the research interest because it is of interest to understand the dilute limit, or the cause of the sporadic misfires should be investigated as a possible malfunction and eliminated. The reviewer added that the input energy requirement for each of the ignition systems tested should be shown. It is understood that it is beyond the scope of this study to reduce parasitic loss associated with highly experimental ignition systems, but it would still be good to know.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that there was wide collaboration, including an engine OEM, modeling player and ignition system developers.

Reviewer 2:

The reviewer commented that good collaboration exists with Ford.

Reviewer 3:

The reviewer said that there is a reasonable level of collaboration with other national laboratories and one LD company. Possibly the project could benefit from additional collaboration with other LD companies if such companies could supply ignition system hardware for evaluation purposes in comparison to recent past work.

Reviewer 4:

The reviewer reported that there were a limited number of collaborators that include one automaker, one simulation software company and two national laboratories. No specific information given to evaluate frequency and quality of those collaborations.

Reviewer 5:

The reviewer indicated that there really needs to be substantial interaction with the Tier 1 suppliers of ignition systems if this project is going to be useful. There needs to be a comparison of any non-conventional ignition system with not only a traditional production-style system but with an inductive system, which is specifically intended for dilute operation (BorgWarner, Diamond Electric, Denso, etc.). The reviewer added that with so much industry work in this area, not having extensive interaction with industry will lead to duplicate work which may not extend the knowledge base at all.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the ignition modeling work is good; there is a huge need for good predictive ignition models. More details on this would be nice to have. The reviewer added that the ignition system testing should have an ongoing interaction with industry and also a continuing evaluation of existing published research so that it is clear how this project is going beyond studies that have already been done by others.

Reviewer 2:

The reviewer indicated that the improved ignition models are an important area and are needed by the industry.

Reviewer 3:

The reviewer stated that the plans seem reasonable for continued progress towards project objectives.

Reviewer 4:

The reviewer commented that the future work addressed clear challenges and barriers, including the absence of consistent guidelines for advance ignition systems, procedures to evaluate ignition systems, and modeling approaches.

Reviewer 5:

The reviewer suggested considering exploring other engine operating conditions (such as lighter loads) with the various ignition systems.

Reviewer 6:

The reviewer asked if there is a way to get the engine to operate at 35% EGR and closer to 45% BTE like Honda has demonstrated. Applying novel, advanced ignition systems like laser based and non-equilibrium plasma systems will then have more significance as to their potential.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer reported that there is potential for significant short-term improvements in FE if dilute combustion can be pushed into the market. Ignition systems and modeling tools are a key enabler for this. The reviewer added that there are ways this project can contribute to what is already going on in this area.

Reviewer 2:

The reviewer commented that extending the operating range of lean burn and EGR-diluted SI engines would improve FE and thus support DOE goals of limiting petroleum usage.

Reviewer 3:

The reviewer observed that this project is more near-term based aimed at understanding and pushing the dilute limit for modest improvements in engine efficiency, but can be applied over a large fraction of the North American fleet.

Reviewer 4:

The reviewer stated that this project supports development of more efficient gasoline power plants.

Reviewer 5:

The reviewer said that this project supports possible future development of lean-burn, DI gasoline engines that might be able to challenge DI diesel overall efficiencies for LD use.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that the funding level appears correct relative to the work plans. The reviewer would prefer to see the funding devoted more to the modeling development or to experiments which are unique from what has been published elsewhere.

Low-Temperature Emission Control to Enable Fuel Efficient Engine Commercialization: Todd Toops (Oak Ridge National Laboratory) - ace085

Presenter

Jim Parks, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

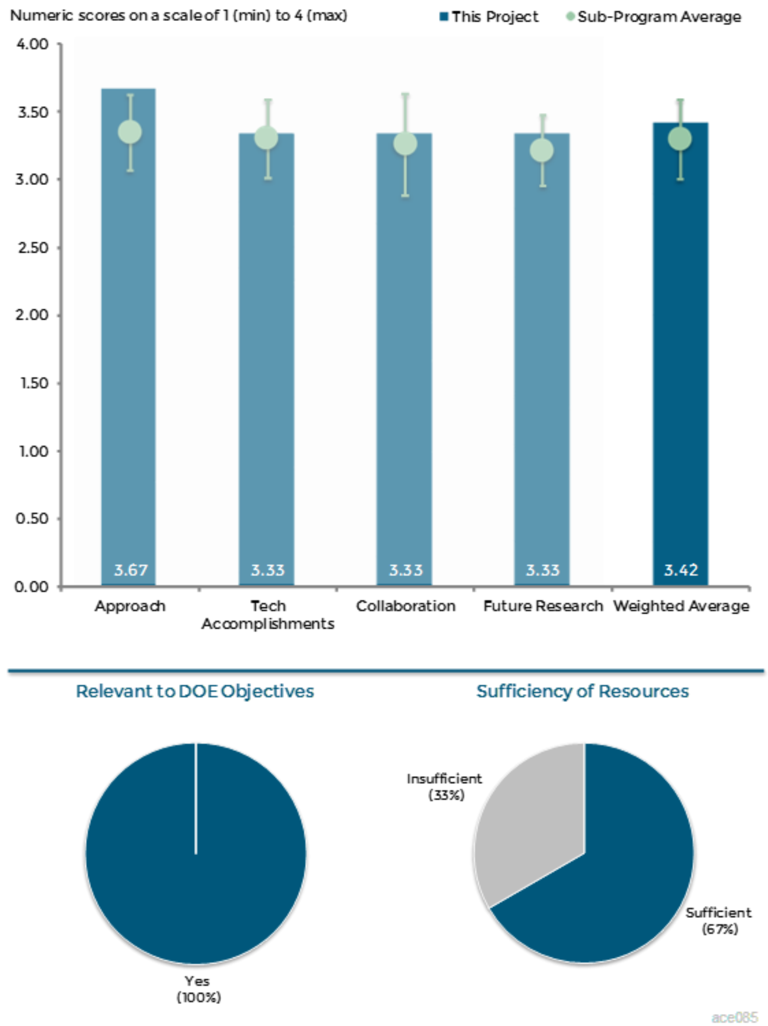

Figure 4-37 Low-Temperature Emission Control to Enable Fuel Efficient Engine Commercialization: Todd Toops (Oak Ridge National Laboratory) – Advanced Combustion Engines

Reviewer 1:

The reviewer observed that this project takes an excellent approach in addressing the challenges in low-temperature emissions control. The steps taken are logical. The reviewer added that candidate materials chose so far are proper based on the scope of this study. Further narrow down in number of material candidates would save time and speed up the project. The process and techniques of evaluating the material are excellent.

Reviewer 2:

The reviewer stated that the overall approach makes sense to expose the candidate catalysts to realistic conditions (hydrothermal aging and sulfur poisoning) as these are the key technical challenges for base metal-(copper (Cu), cobalt (Co) etc.) based catalysts.

Reviewer 3:

The reviewer commented that the project team took the classical approach, literature, synthesis, evaluation. High risk/high reward is likely needed here – entirely different approaches to break the low-temperature barrier. The reviewer added that the project team should have a fundamental understanding first, then iterate. CO poisoning is main obstacle, but realistic exhaust approach and test protocol critical to move into practical application.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer reported that the project team had an interesting early promise on CO/HC inhibition with the co-precipitated CuO_x, CoO_y, and CeO_2 catalyst (CCC). Excellent investigation on dual site mechanism. The reviewer said that the project had a very high caliber work. This could open up other catalyst designs. The reviewer added that aging studies are preliminary, but shows acceptable high-temperature durability for LTC engines. Combo Pt)/aluminum oxide (Al_2O_3) and CCC is logical and delivered results, excellent start. The reviewer also said the palladium /ZrO_2/SiO_2 work is showing some progress from significant work on fabrication. Further options exist for improvement. The reviewer observed that the HC trap concept offers further options worth investigating. Promising results with novel silver (Ag) addition. The reviewer indicated that the project team had a new approach delivering results, good start. The project team claimed to have begun the SCR work but show no plans or data. Yet, the project team has only a half-year to complete this work from when this presentation was put together. The reviewer is suspicious if the project team is really on track as shown on Slide 9.

Reviewer 2:

The reviewer said that good progress has been made in synthesizing and evaluating HC and NO_x trapping materials as well as identifying the individual roles of the of the components in the CuCoCe ternary oxide and potential synergy with standard emissions control components. The findings have been very insightful. Systematic selection of material based on literature review of key journals is an improvement. The reviewer added that more involvement from catalyst suppliers would be sensible as a best practice may not be found in literature in a timely manner.

Reviewer 3:

The reviewer commented that although the critical importance of catalyst durability have been stated by the PI, no data was presented on the effect of sulfur exposure on the CCC catalysts and the hydrothermal aging conditions were rather mild for gasoline engine applications. The synergistic effect of Pt and CCC catalysts was an interesting finding and a more detailed mechanistic study is needed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the various collaborators have the needs covered, excellent. Use of BES for fundamentals, Johnson Matthey for practical/fundamental interface. The reviewer noted cross-fertilization with Ford TWC project.

Reviewer 2:

The reviewer said that more regular technical interactions with industrial partners will help to better define the critical technical challenges (sulfur and severe hydrothermal aging conditions).

Reviewer 3:

The reviewer observed that the collaboration and coordination with U.S. DRIVE team, Johnson Matthey and universities have been good. Reaching out to additional catalyst suppliers could be further beneficial to the project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer reported that the project team had a reasonable plan, but sulfur studies are very critical for CCC and long overdue. The project team has invested heavily in this catalyst, and all this work might be wasted if sulfur effects are significant. The reviewer added at least get a peak in the box before doing any further composition work. This is the risk part of high risk/high return. The reviewer also said that the same is true with the HC adsorber. The reviewer noted that sulfur impacts Ag, and suggested running a couple tests to see if this is a killer.

Reviewer 2:

The reviewer indicated that the effect of sulfur should be the top priority going forward as it is well known that it is the key challenge for PGM-free catalysts.

Reviewer 3:

The reviewer stated that the proposed future work is a natural flow of the project. In some sub-categories which involved multiple choice/combination tasks, the design of experiment technique should be considered to speed up the project.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer commented that this project addresses a key enabling issue with regards to low-temperature combustion engine technology. Low-temperature engines improve FE, which would support DOE objectives of petroleum displacement.

Reviewer 2:

The reviewer stated that the low-temperature catalysts with high efficiencies and durability is a critical enabler for advanced engine technologies.

Reviewer 3:

The reviewer said that oxidation catalysts are emerging as a critical need to enable high-efficiency engines (GCI, RCCI, and LTC).

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that funding seems to be adequate for the remaining tasks.

Reviewer 2:

The reviewer noted that the resources are sufficient to progress the HC/CO oxidation work, but likely not enough for SCR work. The Scope should be re-evaluated. The reviewer added that there is much on the HC remediation plate, and unless more resources are added, the project will miss the NH_3 SCR goals. Otherwise the project will do a partial job on each.

Next-Generation Ultra-Lean Burn Powertrain: Mike Bunce (MAHLE Powertrain LLC) - ace087

Presenter

Mike Bunce, MAHLE Powertrain LLC.

Reviewer Sample Size

A total of seven reviewers evaluated this project.

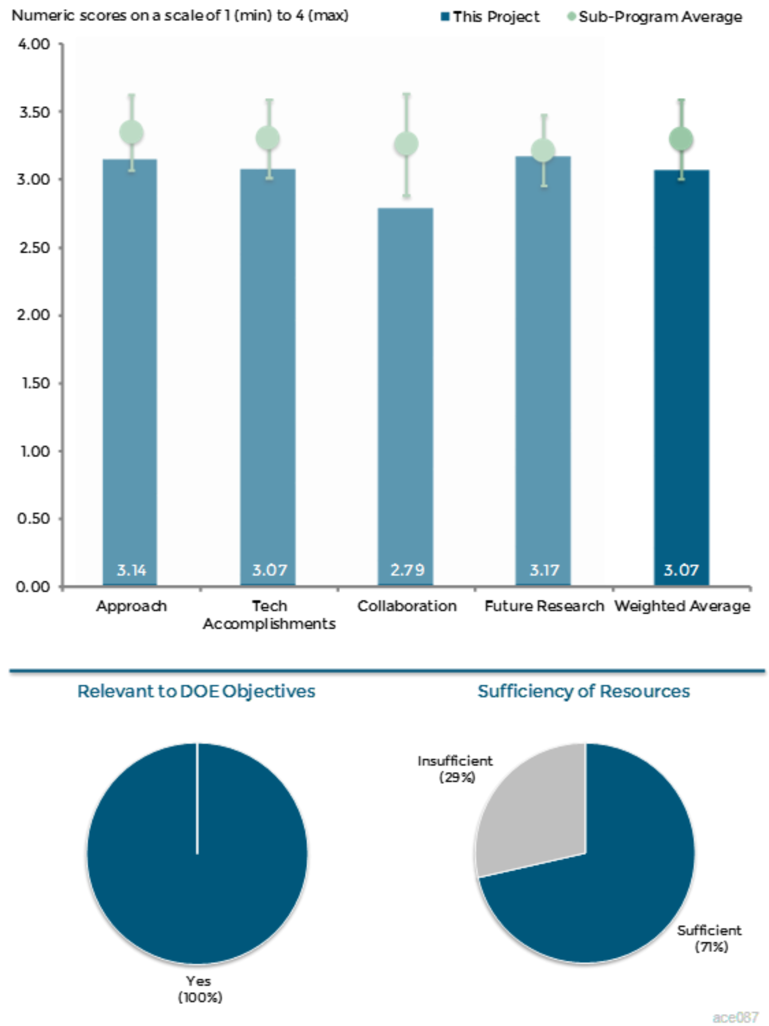

Figure 4-38 Next-Generation Ultra-Lean Burn Powertrain: Mike Bunce (MAHLE Powertrain LLC) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that the project team had an excellent approach to design the engine and develop understanding of pre-chamber and jet ignition technology to achieve 45% thermal efficiency on a LD SI engine and emissions comparable to or below existing SI engines using CFD models, GT Power, single cylinder dyno, and multi-cylinder dyno to demonstrate aggressive targets. The reviewer added that 30% modeled drive cycle FE improvement over gasoline engine from dyno mini-map. Cost-effective hardware for design and manufacturing considering small changes to existing engine hardware. The reviewer also said it would be outstanding to include actual emission target values used, and a future plan or strawman analysis of the potential use pilot jet technology for other advanced combustion and bi-fuel approaches such as diesel pilot NG.

Reviewer 2:

The reviewer reported that this is a very well rounded program for high efficiency gasoline engine research utilizing a turbulent jet ignition (TJI) combustion system with single and MCE and numerical studies being performed in a highly complementary fashion. CFD has been effectively used to optimize the TJI system on a gasoline engine, while SCE test results have been performed for the pre-chamber design optimization. The reviewer added that a MCE was built and preliminary results show good FE. While most of the results are based on efficiency, more comparison results of emissions would be extremely helpful. The reviewer also stated that cost added to the engine by introducing the TJI system needs to be calculated, including the cost of manufacture, control system and maintenance fee.

Reviewer 3:

The reviewer remarked that the project team had an excellent approach in integrated simulation and experimental development. Any lean-burn system is going to raise questions of how emissions will be addressed with confidence. The reviewer added that this needed a little more attention in the project, but was perhaps out of scope.

Reviewer 4:
The reviewer stated that the overall approach being used for this project appears sound and well thought out. The CFD model of the turbulent jet is said to use species concentration in the main chamber to determine ignition. The reviewer added that it was not clear how this development of the model was done. The reviewer asked if there was there some validation of the model with the optical data.

Reviewer 5:
The reviewer commented that lean combustion is a known approach to improve gasoline engine efficiency.

Reviewer 6:
The reviewer noted that the project is not a new technology, but new tools used to refine it, certainly timely. The approach keeps resurfacing so the reviewer believed it had merit, but needs refinement. The reviewer added that the assumption that NO_x is very high for ultra-lean combustion is not necessarily valid. It depends on the exhaust gas conditions and duration. The reviewer thinks a few NO_x measurements would be informative. The reviewer also said the assumption here is that the aftertreatment will have to fix the NO_x problem is always problematic.

Reviewer 7:
The reviewer reported that it does not look like the 45% thermal efficiency goals will be met. Without understanding how criteria pollutant emissions control will be accomplished with this engine configuration. The reviewer asked how drive-cycle FE could be predicted.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted excellent progression through simulation, fundamental experiments, and engineering. Have progressed to multi-cylinder with BSFC numbers looking pretty good. The reviewer asked if the project team is still short of 45%. Still using simulated boosting system.

Reviewer 2:
The reviewer stated that the transition from single cylinder and multi cylinder results are good.

Reviewer 3:
The reviewer observed that good progress has been made against the objectives of the program, with the program going all the way from concept design to MCE testing smoothly and generating very promising results that have been delivered on time. Most of the designed procedures are shown to be very effective. Of particular note is the extensive use of CFD tools to understand the TJI system and to assist the whole engine design. The reviewer asked that because the TJI system has a more constrained feature (nozzles), is there any delay in flame propagation at high speed operating conditions.

Reviewer 4:
The reviewer reported that nice accomplishments in demonstrating the single cylinder and multi-cylinder engine performance improvements. The optical engine data was a nice addition to the metal engine data. It was not clear to the reviewer what criteria were being used for acceptable indicated mean effective pressure (IMEP coefficient of variance (COV) and the slides indicate that the variation was minimal.

Reviewer 5:

The reviewer commented that there were interesting results regarding optimization of the TJI design details. Vehicle FE results need to consider the lean aftertreatment impact on fuel consumption because the NO_x are not low enough to avoid aftertreatment.

Reviewer 6:

The reviewer indicated that there was a significant level of work and analysis demonstrated with data from CFD and dyno testing results. Strong effort results in a nozzle design and discussion of tradeoffs and final design balanced between low speed and high power nozzle requirements. The reviewer added that the project team reported with data that indicated the peak thermal efficiency target has been met. The trade-off design results were also very good at above 40% thermal efficiency over a wide range of BMEP and lambda. The reviewer also said that the project accomplishments can be rated as excellent/outstanding once data is available showing verbally discussed emission results (engine out brake specific HC, CO reported comparable to baseline engine and approximately 40-70% lower NO_x @ lambda=2) with engine out exhaust emission temperatures at ~300°C). Drive cycle FE benefit which was not yet completed/ presented. The reviewer also indicated that clarification was provided that the combustion system is not plug-and-play and that valve train, piston, combustion chamber design is specific to the technology with some data presented in SAE 2015papers.

Reviewer 7:

The reviewer stated that it does not appear that the 45% BTE goal will be met. It also is not entirely clear how boosting and emissions control systems will be modelled adequately to predict drive-cycle FE.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed that there was good collaboration, use of knowledgeable industry advice, and subcontractors such as Ford, Delphi and Spectral Energies. There was excellent to outstanding collaboration through specific third-party confirmation of testing or analysis toward other applications such as NG/diesel pilot through an OEM, Tier 1 supplier, university or national laboratory.

Reviewer 2:

The reviewer said two subcontractors and vague comments about unspecified university contacts, not really exciting.

Reviewer 3:

The reviewer said that collaborations were limited to subcontractors.

Reviewer 4:

The reviewer commented that while there appears to be much collaboration with industrial partners, little use of the government laboratories seems in evidence. The reviewer would have thought that some optical engine tests with the TJI system might have proven useful. Also, the role of the various universities alluded to in the presentation should be more clearly delineated.

Reviewer 5:

The reviewer thought better coordination with Ford would be helpful with respect to establishing the hardware and FE implications of lean-operation emissions control systems.

Reviewer 6:

The reviewer stated that universities (not named in the presentation) were cited during the question and answer session. The reviewer suggested please include this in the presentation for future Annual Merit Reviews. The reviewer added that it was not clear what the role of the optical engine test lab (Spectral Energies) was in the project. The reviewer asked if this partner contributed expertise, or just provide data for Mahle interpretation. While the value in the optical data was apparent, it is difficult to evaluate their contributions.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the project team had a good plan to execute final project activities; MCE testing, mini-map generation, vehicle drive-cycle FE analysis, and system-level analysis of TJI operating strategy across the engine map. Excellent to outstanding is to also report emission benefit and potential aftertreatment approaches and savings and to consider pilot design and control methodologies on other critical applications such as dual fuel or dedicated natural gas.

Reviewer 2:

The reviewer reported that future work showed a good extension of present study. After generating engine maps and vehicle system drive-cycle analysis, it would be interesting to see the overall cost reduction analysis, including the TJI system, after-treatment system and operating cost.

Reviewer 3:

The reviewer said that the remaining steps are well-planned, although few key items (like emissions) are not in scope of project.

Reviewer 4:

The reviewer said the future plans look sound.

Reviewer 5:

The reviewer would really like a track of NO_x emissions with the optimization

Reviewer 6:

The reviewer said the project has ended.

Reviewer 7:

The reviewer stated that this is a project where it was not clear if the concept would work or not, and would not be pursued by industry because of this risk. Therefore, it is appropriate for DOE to invest in projects such as this.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that ultra-lean gasoline is a great goal. It will make a difference with petroleum displacement for passenger vehicles as long as it can meet the emission standards.

Reviewer 2:

The reviewer commented that this project used pure gasoline as the studied fuel, good FE was achieved as indicated in the presentation. The TJI system could also be used on a NG engine, bio-fuel engine or other future engine types, which supports the overall DOE objectives of petroleum displacement.

Reviewer 3:

The reviewer reported that the novel high-efficiency system appears suitable for widespread use.

Reviewer 4:

The reviewer said that drive cycle target FE improvement of 30% can make significant impact on the LD fleet as the technology could potentially be made available medium term on new vehicles. TJI could be enabling technology for improved dedicated NG vehicles and diesel pilot NG vehicles.

Reviewer 5:
The reviewer stated that multi-cylinder engine results show promising efficiency results.

Reviewer 6:
The reviewer said improved efficiency for reduced petroleum consumption.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that more resources would enable more complete final demonstration.

Reviewer 2:
The reviewer remarked that this was an excellent project and technology approach. The project is ending in 2015, and the technology agnostic FOA allows significant flexibility to look across industries and evaluate promising technologies.

Reviewer 3:
The reviewer said that resources appear sufficient.

Reviewer 4:
The reviewer commented that Tier 3 Bin 30 emissions control should have been included as part of this work but it was outside the scope of funded work.

Development of Radio Frequency Diesel Particulate Filter Sensor and Controls for Advanced Low-Pressure Drop Systems to Reduce Engine Fuel Consumption: Alexander Sappok (Filter Sensing Technologies, Inc.) - ace089

Presenter

Alexander Sappok, Filter Sensing Technologies, Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

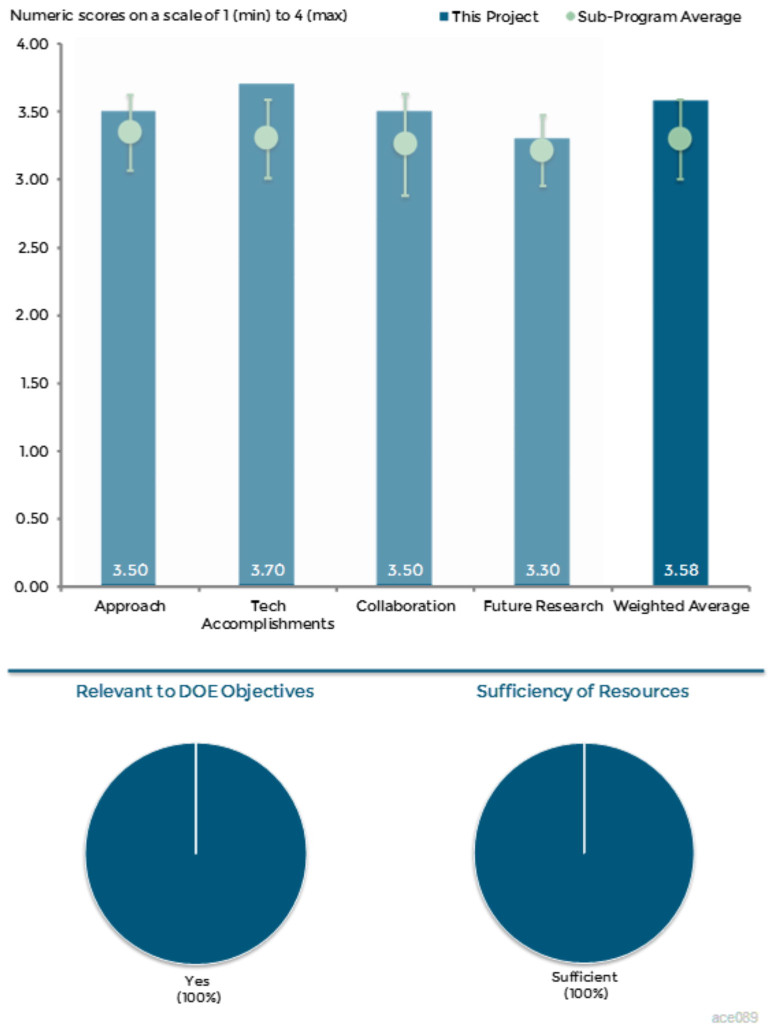

Figure 4-39 Development of Radio Frequency Diesel Particulate Filter Sensor and Controls for Advanced Low-Pressure Drop Systems to Reduce Engine Fuel Consumption: Alexander Sappok (Filter Sensing Technologies, Inc.) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that the use of the radio frequency (RF) signal to understand soot load is great. The usefulness of this data could be useful not only to trigger and end regeneration, but also for some level of OBD on engine out conditions. The reviewer added that the presenter stated this technology is not applicable to the most popular soot filter material, silicon carbide (SiC), which is rather disappointing in one sense. If this becomes a commercial product it could be a boom for enabling less costly cordierite material, but at the same time, this material is not as robust.

Reviewer 2:

The reviewer observed that this project is well thought out and technically sounds. RF sensors seem to provide more information on soot loading than the pressure drop signal typically used in production vehicles. The reviewer said that its capability of distinguishing ash from soot is a big plus. The capability of identify uneven soot distribution in the filter is also very significant. The reviewer added that as the method has been presented, the capability of quantifying ash loading and uneven soot load on filters has not been utilized.

Reviewer 3:

The reviewer stated that determining the optimum regeneration time and duration in particulate filters given the standard pressure difference approach (corresponding to matter accumulation) has been a challenge for after-treatment manufacturers in terms of accuracy, efficiency and durability. The authors' methodology of developing a patented radio frequency RF-DPF particulate filter sensor to directly measure soot and ash levels and to control in real-time the after-treatment system operation based on those measurements is innovative and effective, enhancing the DPF-related fuel consumption and durability. The reviewer added that these critical barriers are sharply focused on and addressed in their approach, as presented in Slides 5 and 6, which shows multiple technical steps from research stage to production and commercialization.

Reviewer 4:

The reviewer said that this is a very novel sensing approach that looks like it has potential to improve controls and reduce fuel consumption.

Reviewer 5:

The reviewer commented that the approach was novel, well executed approach to DPF monitoring, OBD and active regeneration.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that there are obviously demonstrated great technical achievements using the proposed RF-DPF sensor versus the pressure difference approach: accuracy in soot measurement during DPF loading and regeneration; reduction in regeneration time and frequency by immediately stopping the HC dosing once oxidation is complete; multi-function (soot and ash) design concept within chip set dimensions; superior sensitivity regeneration for biofuels; additional option of being used as a fast soot sensor for advanced controls; soot load level detection at idle; accurate measurement of ash load over time, invariably of ash deposits; after-treatment-related fuel savings of up to 3%. The reviewer added that the functional principle (see Slides 23 and 24) of measured change in resonant frequency modes using dielectric properties of contaminants (for example, soot) versus clean filter can be universally applied, regardless of DPF geometry, materials, temperature that is easy zeroing, and also reliable and suitable for on-board control and diagnostics. The reviewer also stated that even though the RF-DPF sensor clearly shows superior performance in many aspects, reviewer did not find a representation of overall system cost reduction. Any innovation, regardless of how technically superior is to the current production baseline, may turn away the manufacturers from adopting it if it is not economically advantageous (less expensive), because customers may not be willing to pay more. The reviewer said that perhaps a basic representation showing obvious financial gain would help.

Reviewer 2:

The reviewer stated that there were very clear results that show the improvement in sensing accuracy compared to the incumbent delta pressure (P) sensor. The fuel savings are significant in reducing wasted regeneration fuel and improving the accuracy of a regeneration event with real time feedback. The reviewer added that the correlation to an AVL micro soot sensor is an incredible result.

Reviewer 3:

The reviewer reported that significant progress has been made with sensor related development, integration and testing. Demonstration of fuel saving (DOE goal) is far more convincing than previous year. The reviewer added that testing included both LD and HD engines helps to expand the potential field of application. Demonstrations of fast sensor response, accuracy and durability are significant accomplishments.

Reviewer 4:

The reviewer said that everything shown so far has been very encouraging. It will be much more interesting to see data that shows the ability to decipher mal-distribution of soot. Also, the reviewer stated it seems there should be an inclusion of contaminants such as heavily loading the soot with HC. For example, when a vehicle idles in cold environments overnight, soot and HC can accumulate in the soot filter. The reviewer asked how the sensing technology responds. Also, the reviewer asked do water and sulfur affect the signal accuracy.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated that collaboration and coordination with industry partners, a national laboratory, city fleet and/or subcontractors has been excellent.

Reviewer 2:

The reviewer stated very good coordination with national laboratories and Corning.

Reviewer 3:

The reviewer said that it is good that there is a fleet user to put miles and heat cycles on the sensors to test the long term stability and durability of the sensor.

Reviewer 4:

The reviewer remarked that there is a close, appropriate collaboration with other institutions. Slide 7 demonstrates an effective coordination with multiple technical partners regarding sensor design, benchmarking, materials selection, controls development and on-road fleet testing.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that it seems that the RF-DPF sensor withstood the harsh, unfriendly testing and calibration actual exhaust gas conditions, where damaging effects, such as temperature spikes during active regenerations or other harmful gases may have premature deteriorating effects. Filter Sensing Technologies, Inc. is already advertising this RF-DPF sensor on their website and offer to have it tested by other engine manufacturers. The reviewer added that it will be very interesting to hear feedback after actual road mileage, long-term testing conditions. Of ultimate but not least consideration should be the commercial/manufacturing plans towards proving an actual cost gain while using the RF-DPF sensor.

Reviewer 2:

The reviewer commented that the proposed future work is sound as the project team focuses on evaluation of optimized calibrations and controls to quantify performance relative to baseline (the delta P + Model) in a wide range of engine and vehicle applications.

Reviewer 3:

The reviewer reported that the presenter explained that the future work will include some purposeful mal-distribution testing. Testing the mal-distribution could really prove the worth of the technology because there have been so many field issues with partial regenerations, multiple events, that eventually lead to failures. Also, the reviewer said that it would be good to see if this technology can find failed parts that would be better than downstream soot sensors for OBD purposes.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer commented that any reduction in fuel consumption, including these demonstrated 1.5 to 3% after-treatment-related fuel savings, supports the overall DOE objectives of petroleum displacement.

Reviewer 2:

The reviewer said that the results show a direct impact on reducing fuel consumption to regenerate DPF.

Reviewer 3:

The reviewer reported that if successful, the technology would results in fuel saving that would support DOE objectives of petroleum displacement.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that resources appear adequate.

Reviewer 2:

The reviewer said that funding seems to be adequate for the remaining tasks.

High-Dilution Stoichiometric Gasoline Direct-Injection (SGDI) Combustion Control Development: Brian Kaul (Oak Ridge National Laboratory) - ace090

Presenter

Brian Kaul, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of seven reviewers evaluated this project.

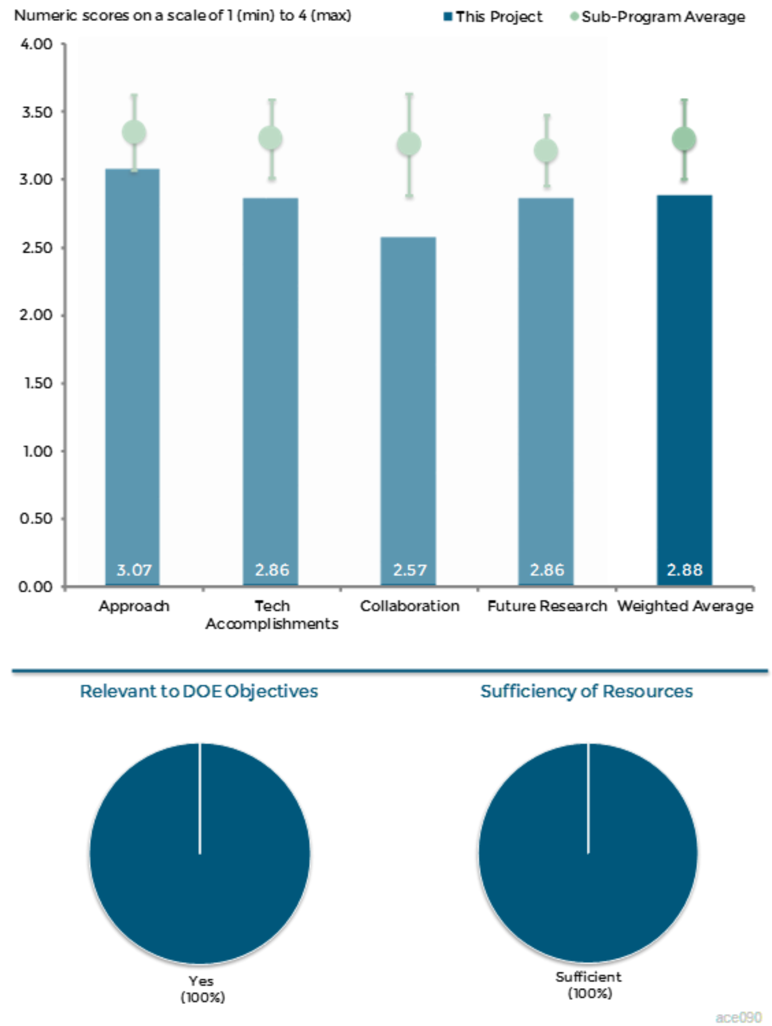

Figure 4-40 High-Dilution Stoichiometric Gasoline Direct-Injection (SGDI) Combustion Control Development: Brian Kaul (Oak Ridge National Laboratory) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer reported that the project team had a very interesting approach towards combustion control and near edge stable operation. This research is important for both controls and improving misfire diagnostics. The reviewer added that the project had a cost effective and real time combustion analysis with cylinder pressure on-board a production vehicle will be challenging. Hence, this research and development effort should continue for both the strategy itself and its implementation.

Reviewer 2:

The reviewer commented that the use of tools to reduce cycle-to-cycle variation and validate on an engine is a good approach.

Reviewer 3:

The reviewer stated that the project is developing controls using deterministic behavior to reduce cycle combustion variability. A symbol-sequence statistics analysis was used, where the method describes a partition data and identification of sequences. The reviewer added that the objective seeks to extend the SI dilution limit though it may appear to be more of an enabler. The approach does not focus on the physics or new hardware of the engine platform but rather data analysis. The reviewer also said that the approach is believed to be marginally effective.

Reviewer 4:

The reviewer pointed out that this project very effectively addresses need for combustion stability control to enable high efficiency at part-load, highly-diluted GDI engine operation regime. For FY 2014-15, the project has adopted a solid approach: characterize cyclic variability in high EGR operation; assess symbol-sequence statistics analysis; develop next-cycle control scheme; implement next-cycle control scheme on General Motors LNF 2.0 liter turbocharged GDI engine and assess its efficacy.

Reviewer 5:

The reviewer noted that it would be good to quantify the potential opportunity to improve engine efficiency with this work. The reviewer suspected that it is fairly small.

Reviewer 6:

The reviewer stated that this project enables engines to operate at the dilute limit. High dilution engines are one pathway to high efficiency engines.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said that the good progress with accomplishments include: showed that the approach of symbol sequence analysis is effective even with real world poor quality data (relative to the lab environment), improved understanding of the cycle-to-cycle dynamics needed to develop effective control structure, discovery that a restrike spark can help reduce misfire events, although retarding the restrike further can be counter-productive resulting in increased COV and misfires.

Reviewer 2:

The reviewer commented that the work is being carried out on a 4-cylinder GDI engine. High fidelity data was used and later down-sampled for possible production implementation. The authors may note that down sampling is likely not needed as there are production like controllers developed that can retain the high fidelity, for example, with 0.5 degree crank resolution). The reviewer added that the work included a multiple spark strategy as a control over cyclical dynamics. The effects of cycle-to-cycle perturbations of ignition and fuel quantity were examined. Also, the reviewer said the work identified a symbol sequence to identify event signatures that may be dominated by for example internal or external EGR. The approach is seen as an enabler to operating at high-dilute regions. Significant work is required to verify and provide evidence that this is the case.

Reviewer 3:

The reviewer said that the above approach has enhanced and quantified fundamental understanding of cycle-to-cycle dynamics and led to a very interesting symbol-sequence based control concept for a GDI engine (Slides 8-16).

Reviewer 4:

The reviewer commented that Progress has been made, but more focus should be on demonstrating the benefit of the specific control algorithm technique. The reviewer said that the big question is if nonlinear dynamics, information theory, and symbol sequence statistical analysis show promise to enable engines to operate at their dilute limit, and that this should be answered as soon as possible. The reviewer added that it seems like the project is getting defocused by going down some trails that are of minor importance, or not high priority.

Reviewer 5:

The reviewer said that it is important to understand if the technique will work in a production engine controller environment and sensor set. It is good to see technique is robust to lower quality data.

Reviewer 6:

The reviewer indicated that progress made towards symbol sequence analysis to understand cycle to cycle variations, and demonstrating the methodology holds merit even with real life data with low quality.

Reviewer 7:
The reviewer indicated that there does not seem to be a lot of progress since the last AMR. The data quality analysis is interesting, but not relevant if the whole approach does not work. The reviewer added that it is more important to prove out the concept with high quality data and then later go back and consider lower quality data.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the collaborations appear limited to two equipment/controls suppliers

Reviewer 2:
The reviewer reported that the project is tied to the ORNL-Cummins CRADA, which appears very valuable. The reviewer added that little information is provided by the contributions of the other partners such as National Instruments, Bosch or Argonne National Laboratory. This could be better described.

Reviewer 3:
The reviewer stated that the team has brought in industry and laboratory partners and is seeking additional industry assistance in the controls area.

Reviewer 4:
The reviewer pointed out that collaborations are minimal and need to include OEM control teams to really have an impact.

Reviewer 5:
The reviewer indicated that extensive collaboration with expert controls personnel at an OEM is necessary to make this project relevant and useful. It is recommended that this collaboration be sought.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that having characterized the problem and the levers that affect it, the next step is to build a control mechanism to overcome the instability and reduce CCV. This will be challenging, but the team has put a lot of good work in so far, so the path is reasonably well laid out.

Reviewer 2:
The reviewer indicated that the online model based control using this methodology, also in transient operation, is a future research to look forward to.

Reviewer 3:
The reviewer commented that plans seem to be supported by the U.S. DRIVE ACEC Technical Team and to build on progress and advance toward ultimate project goals.

Reviewer 4:
The reviewer stated that the work in 2016 to 2017 was described, this includes the development or models and control strategies. The work will be challenging based on the results to date but the reviewer looks forward to seeing how it progresses.

Reviewer 5:
The reviewer pointed out that it is not clear what the approach will be for next-cycle control.

Reviewer 6:

The reviewer reported that the primary focus should be on demonstrating the ability of the control algorithm to operate safely at the dilute limit.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that the project team improved fundamental understanding and development of improved control systems to reduce cyclic variability and extend the SI lean dilution limits will help to assess feasibility of this approach to achieve DOE objectives.

Reviewer 2:

The review reported that the control development work is necessary for implementation of advanced combustion techniques. This particular project is tied to other current programs. Any progress made here will be applicable across a wide horizon.

Reviewer 3:

The reviewer stated that a practical control strategy would allow high-dilution EGR operation of GDI engines, increasing their efficiency and reducing petroleum consumption.

Reviewer 4:

The reviewer commented that the active combustion control is a very important research topic for advancing engine efficiency and non-traditional combustion regimes.

Reviewer 5:

The reviewer observed that this project does not extend the dilute limit of an engine. It simply enables the engine to operate at the dilute limit.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that it is actually surprising what has been done with the budget so far, but the progress is so good, have little doubt the team can continue to make progress with the requested resources.

Intake Air Oxygen Sensor: Claus Schnabel (Robert Bosch) - ace091

Presenter

Claus Schnabel, Robert Bosch.

Reviewer Sample Size

A total of five reviewers evaluated this project.

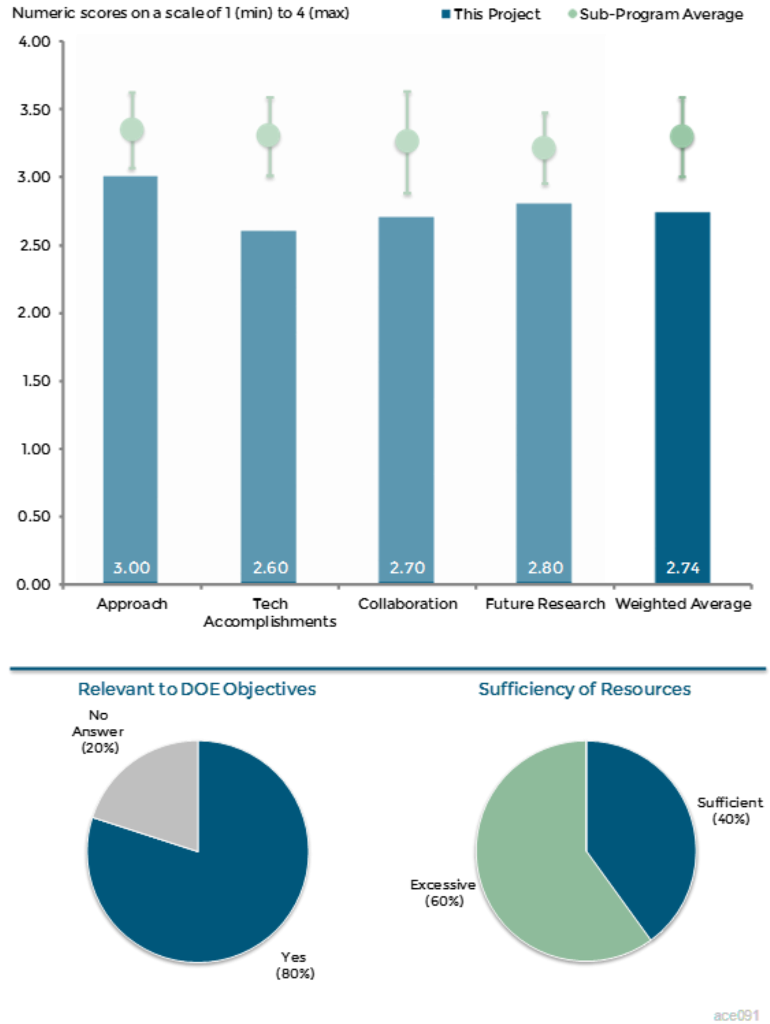

Figure 4-41 Intake Air Oxygen Sensor: Claus Schnabel (Robert Bosch) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the approach was excellent, if fairly typical, for a development process, involving a close coupling between physical experimentation and computational simulation.

Reviewer 2:

The reviewer said the work is certainly sound. The reviewer could understand why intake air oxygen (IAO_2) is needed for cEGR monitoring and control. It is kind of hard to get excited about this because it appears to be based largely on an off-the-shelf wide-band O_2 sensor.

Reviewer 3:

The reviewer stated that Bosch has a good basis for understanding the O_2 sensing needs and how to make sensors that work reliably. Starting with the exhaust O_2 sensor and making the needed modifications is the best way to get the most out of the resources.

Reviewer 4:

The reviewer reported that this project is well designed in terms of oxygen sensor development, installation on the engine; however, the investigators failed to address the concern as what is necessary accuracy of the sensor required for cERG control. Accuracy target of plus/minus 2% deltaO_2/O_2 is quite high. It is not clear if this requirement came from cEGR partners as an integrated part of overall control strategy.

Reviewer 5:

The reviewer reported that the approach of carrying over a production sensor element is not very cutting-edge. The reviewer suggested investigating improved sensor elements. This project looks like product development. The reviewer added that NGK published an SAE paper on using an intake O_2 sensor to control EGR in 1988.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that overall, the progress and accomplishments have been good. It is mentioned that the engine simulation to demonstrate sensor benefits has been completed as a milestone, but the presentation does not show any results. Also, the reviewer said some of the technical accomplishments, such as Identified sensor location, seem to be very incremental. It would have been helpful to include comments from previous year's presentation and actions taken to incorporate their suggestions into this year's effort.

Reviewer 2:

The reviewer noted that Bosch has plenty of expertise in O_2 sensors, which has been well applied in this project. There were technical accomplishments with regards to the sensor fit well with the project and DOE goals.

Reviewer 3:

The reviewer observed that it seemed as though the team has tackled the really difficult tasks and have a means to compensate for the changing environmental conditions. The reviewer would have expected the work to be done much in parallel to nearly all tasks, and would have expected to see much more compensation work having been done as the first order to this project (pressure and Lambda-like compensation routines). Also, the reviewer thought a big open question is how well this would work on diesel. As much money that has been spent and no data for diesel is a very big hole in the entire plan, diesel is always lean, and it would be expected, diesel might be the first adopter for such a sensor. The reviewer asked how this could not have been in the very front end of the project.

Reviewer 4:

The reviewer reported that progress is slow for such an expensive project. Cross sensitivity to hydrocarbons in purge vapors or crankcase vapors could be a significant impediment to implementation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that the collaboration with Clemson University and ORNL is good, it might be useful to have some engine makers directly engaged to get their input as part of the program.

Reviewer 2:

The reviewer said that there is no mention of input from potential customers. The reviewer suggested that the project team collaborate with an OEM to ensure that customer requirements are met.

Reviewer 3:

The reviewer stated that collaboration and coordination with partners seems to be lacking or not shown. Hopefully, this situation will change for the future tasks.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer observed that the future directions are sound and logical. Bosch is well qualified to take on the sensor development. The reviewer added that the demonstration of sensing benefit require close collaboration with cEGR partners. It should occur during this phase of the project.

Reviewer 2:
The reviewer commented that the projected tests to demonstrate the impact on efficiency and emissions performance of this sensor (presumably in comparison to differential pressure sensors) for cEGR application in engine tests will be crucial to ultimately judging whether the extra cost is justified. The investigators are encouraged to make this a priority.

Reviewer 3:
The reviewer suggested that a demonstration of the benefits of IAO_2 sensing is the most promising, but the reviewer also believed that would be best demonstrated if there were an engine OEM involved. The reviewer noted the work being done does not include a car manufacturer, as it would seem the OEM would be the ones to specify the use of the part.

Reviewer 4:
The reviewer reported that future plans are very broad and lack precision to assess probability of success.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer reported that this is relatively accurate information on intake oxygen could potentially improve cEGR control strategy thus improve the FE which supports the DOE objective.

Reviewer 2:
The reviewer stated that the technology promises to aid efficiency gains which will aid in reducing petroleum consumption.

Reviewer 3:
The reviewer said that the project is an enabler to implement cooled EGR, the intake O_2 sensor could lead to reduced fuel consumption.

Reviewer 4:
The reviewer remarked that this project is really focused on emission control, and if this device is able to improve emission control on lean burn engines, then it will help achieve DOE reduced oil dependency.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the funding seems to be adequate for the remaining tasks.

Reviewer 2:
The reviewer said that resources seem adequate.

Reviewer 3:
The reviewer stated that it is not clear why DOE is paying for product development at Bosch.

Reviewer 4:
The reviewer commented that Bosch is a world leader in the development and sales of O_2 sensors. This sensor would likely have been fully developed and commercialized entirely without funding from DOE because there is an OE need for cEGR systems.

Reviewer 5:
The reviewer reported that the work of testing for water intrusion, salt spray and the like, seemed to be excessive for proving out an intake O_2 sensor that is a derivative product. This is the sort of work that would be done in a path to production, which is not what should be done on the DOE's money, but rather on the

supplier's money. The reviewer added that in total, it is understandable the high cost of development, but when considering this derivative product program ran for $4.5 million versus some national laboratories that ran sensor programs that were $1 million for something brand new, it seems excessive.

High-Efficiency VCR Engine with Variable Valve Actuation and New Supercharging Technology: Charles Mendler (Envera LLC) - ace092

Presenter

Charles Mendler, Envera LLC.

Reviewer Sample Size

A total of eight reviewers evaluated this project.

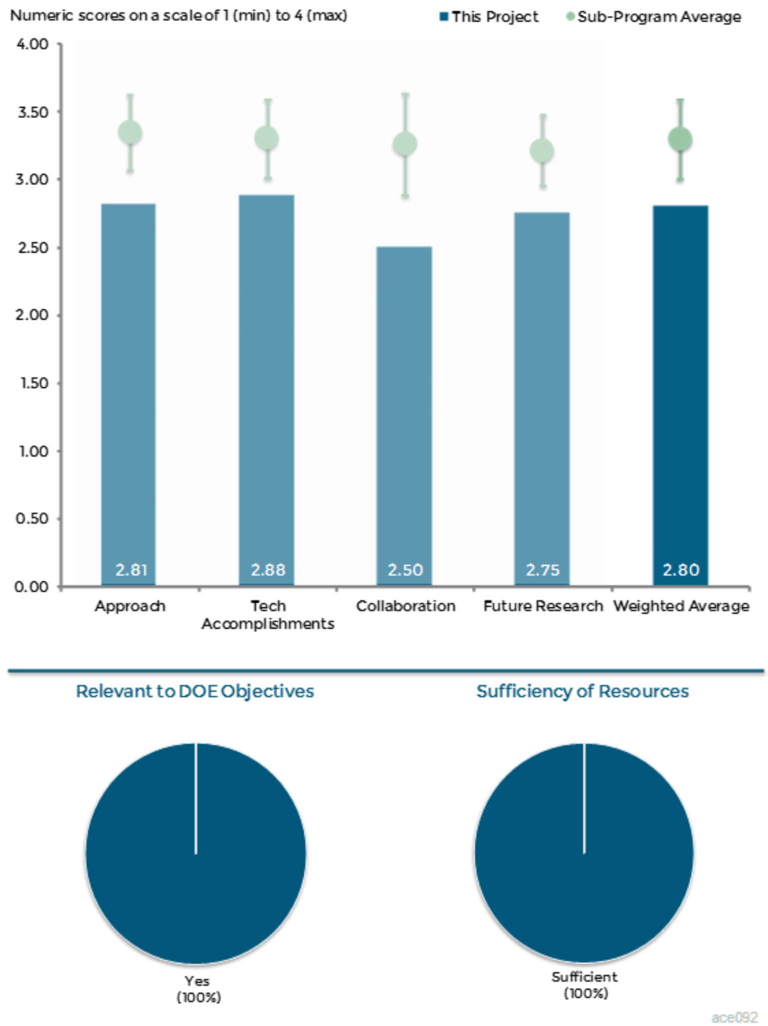

Figure 4-42 High-Efficiency VCR Engine with Variable Valve Actuation and New Supercharging Technology: Charles Mendler (Envera LLC) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated there was a project re-scope from 2014 AMR vehicle and dyno scope to a dyno engine only development with simulated vehicle results. This is an excellent adjustment to successfully achieve technical proof of concept more quickly and is better aligned with current budget. The reviewer added that a successful result from PI review of state of the art is new mechanical design for VCR device, which has simpler implementation on the dyno and more desirable packaging envelope for production application than prior eccentric crankshaft device. Current device could potentially retain much of production tooling and reduce investment upon successful proof of concept as majority of base engine geometry and many production components can be maintained or modified slightly for variable compression ratio implementation reducing time and risk. The reviewer stated that the GT-Power modeling of best case performance with Eaton analysis and re-design of two step lost motion cam device is also very good approach. Techno economic value analysis effort outstanding change to scope.

Reviewer 2:

The reviewer observed that the approach is rather unique in this program by incorporating both VCR and variable valve timing. The approach allows to application of the Atkinson cycle in a unique way to promote high engine efficiency. The reviewer added that the project includes supercharging as a means to hit very high power output.

Reviewer 3:

The reviewer noted that this appears to be a novel variable compression ratio (VCR) approach. The reviewer thought considerable work will be necessary to characterize both the durability and NVH characteristics of this engine design. It is not clear to this reviewer why a mechanical supercharger was chosen instead of an exhaust-driven turbocharger or a combined turbocharger and e-charger, particularly when considering the CAFE target of 40% improvement.

Reviewer 4:

The reviewer commented that this project was a very hardware oriented program looking at VCR with VVA and higher PR supercharger. As VCR is in itself not completely new concept, this project appears to be evolutionary than revolutionary, but some significant results have been achieved. The reviewer added that it appears to be lagging a little behind a linear timeline from the time and money spent to date. As a lot of what is shown is feasibility study, there is a lot that has yet to happen to get to the all up hardware engine testing stage. Also, the reviewer said there seems to be very little analysis work going on to support this project, some GT-Power and finite element analysis (FEA) results are shown or mentioned. It would be good to be doing some CFD particularly in cylinder to help support claims like best part load efficiency occurred with an internal EGR dilution value of only 12%. The reviewer stated that this finding indicates that the Atkinson cycle with moderate dilution values may provide an easier pathway to attaching high efficiency than low temperature combustion and extreme-dilution approach. This may be asking too much of GT-Power to conclusively demonstrate.

Reviewer 5:

The reviewer stated that there are many technologies stacked together here. The VCR mechanism is probably the most difficult to achieve, and yet it may not be the largest contributor to FE gains when compared to the boosting and VVA Atkinson features. The reviewer added that needs further information to justify the emphasis on the VCR. Also, it is concerning that there appears to be a shift to a different design of VCR, very similar to the Toyota approach. The statement to upgrade to the Toyota VCR is a peculiar mid-project course correction. The reviewer stated that presentation mentions first public showing but did not list patent status, the reviewer may have missed it. There is positive-looking development is the Eaton supercharger with integrated charge cooling.

Reviewer 6:

The reviewer reported that all VCR systems are mechanically complex, and the proposed concepts are no different. The approach to use production GM cylinder head is a good idea to avoid the difficult task of designing and manufacturing a cylinder head.

Reviewer 7:

The reviewer is skeptical of this approach, the mechanical design demands can be great and durability may be a problem; that said, it is appropriate to try. That is the mission of the DOE. The reviewer added that eliminating the in-vehicle demo is probably good. This is a daunting mechanical study.

Reviewer 8:

The reviewer observed that details of the approach and process that will be used to claim 40% improvement in FE were not provided. PCP may be exceeding design limits of the engine being modified, so claims of high power density may not be a fair apples to apples. The reviewer added that the temperatures in-cylinder are very high, but not quoted (GT-Power modeling).

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer observed that the GT power modeling that was completed and presented are a very good accomplishment for the project. Some caution should be exercised in the use of the modeling results, because there is no engine data yet to validate those modeling results.

Reviewer 2:

The reviewer commented that a redesign of a VCR device to linear block movement is a solid accomplishment from eccentric crankshaft device improving both proof of concept test efficiency and potential production possibilities. GT Power modeling of best case performance with Eaton analysis and re-design of two step lost motion cam device is also good approach.

Reviewer 3:

The reviewer commented that as noted above, some interesting results have been shown, but the tougher work of hardware demonstration is still ahead. The team needs to seriously consider adding more tools and resources to aid in achieving the ultimate goals of the project.

Reviewer 4:

The reviewer was expecting to see design details for the VCR mechanism, not an entirely new concept; however, the new concept looks like a much more promising approach. Loading of the eccentric mechanism will need to be carefully considered because cylinder pressure loads act directly on the mechanism. The reviewer explained that the comment regarding 12% internal dilution on Slide 9 is not surprising as this is not just a function of dilution but also of the impact of valve events on pumping losses. The addition of external dilution would improve efficiency further assuming the combustion system has adequate dilution tolerance; however, as this project is focused on VCR, this is an additional complication best deferred to follow-on work.

Reviewer 5:

The reviewer reported that comparing the 2014 and 2015 schedule suggests some major changes and delays have occurred. There was approximately a year shift in milestones. The reviewer said that the consideration to go to a substantially different VCR design indicates issues with original approach which was the basis for award. The major positive accomplishment was the Eaton supercharger development/innovation.

Reviewer 6:

The reviewer observed that much of this is mechanical design and modeling.

Reviewer 7:

The reviewer stated that the presentation needs to be better organized to clearly communicate the engine simulation and its projections. This should include a complete description of the engine architecture or a reference to it. The reviewer added that the program supercharging work is interesting, especially the new concept provided. The addition of this work is rather separate from what appears to be the main effort. The reviewer warned that the authors should not allow this work to compromise the VCR-VVA work.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that there was excellent collaboration with Tier 1 valve train supplier Eaton and subcontractor for GT Power model to re-design valve train. Good efforts to front load controls effort with industry suppliers and to initiate some coordinated feedback from vehicle OEMs.

Reviewer 2:

The reviewer reported that the program has a strong relationship with Eaton. The program should strive to enlist a similar OEM partner over the course of the next year.

Reviewer 3:

The reviewer observed that the coordination with Eaton appears to be good. This project would benefit from auto industry partners. The reviewer added that development of the combustion system, coordination of the combustion system design with the VCR system, and engine calibration across a large design space would benefit from further partnership with the DOE national laboratories, one of the major auto companies, or a major engineering design firm such as AVL, FEV, Ricardo, and IAV.

Reviewer 4:

The reviewer stated that there are strong contributions from Eaton.

Reviewer 5:

The reviewer commented that the collaboration with Eaton is encouraging. This reviewer also pointed out that "sighting" on Slide 23 should probably be "citing."

Reviewer 6:

The reviewer said that in describing collaboration themselves, the researchers noted that the interest from the OEs, component manufacturers, and other R&D organizations is welcomed. The reviewer could not agree more, compared to the 20 or so other projects being reviewed by the reviewer this year, this has perhaps the weakest collaboration ties to laboratories, universities, and engine makers. More work to cultivate such partnerships is definitely recommended.

Reviewer 7:

The reviewer noted that collaboration with an engineering design house could provide a critical assessment of the mechanical design and integrity of the engine.

Reviewer 8:

The reviewer explained that the project could benefit from some academic involvement for more sophisticated simulation of combustion effects from the added supercharging along with the Atkinson cycle combustion.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer reported that the project is focused on the mechanicals, yes. Modeling has limited value if the mechanicals cannot deliver.

Reviewer 2:

The reviewer said that the short term (next year or so) of work is described, but not much in the out years where things are bound to get very interesting (engine builds, testing, etc.). Again the team is suggested to get more outside partners involved, particularly if the team can bring analysis capability onboard.

Reviewer 3:

The reviewer observed that the project team revised variable compression device design using variant of production Eaton supported valve train pathway to design Atkinson/ Otto cycle engine concept, implemented on dyno, and use dyno data to project vehicle results is a strong method to overcome technical and commercial barriers. Proposed future research and partners are currently very good and can be improved with definition of experienced controls development method and /or partner(s) to possibly leverage hardware for multiple control strategy developments once hardware is available.

Reviewer 4:

The reviewer stated that the work is clearly indicated. This work should include a more complete description of the new VCR architecture and the challenges in its implementation.

Reviewer 5:

The reviewer said that the best part of path forward would be to validate the gains from the Eaton supercharger. If the down select of VCR method goes to VCR number two, the distinctiveness of the project will seem to diminish because number two is so close to a Toyota system.

Reviewer 6:
The reviewer noted that the plan looks okay. Please put emphasis on the hardware build and test results that are needed for the modeling validation.

Reviewer 7:
The reviewer commented that the future work needs to include mechanical design analysis of eccentric mechanism that raises and lowers cylinders and head.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer indicated that the project goal to develop and demonstrate a successful, cost effective, production feasible VCR device with potential to achieve 10-25% FE improvement while adding engine flexibility for alternate fuels, bi-fuels, and advanced combustion regimes clearly supports DOE objectives.

Reviewer 2:
The reviewer pointed out that improved FE always supports the petroleum displacement objectives.

Reviewer 3:
The reviewer said yes, the development of technologies such as VCR are important and so its application and integration into the powertrain.

Reviewer 4:
The reviewer commented that this technology should improve efficiency, reducing petroleum usage.

Reviewer 5:
The reviewer observed that variable compression is a proven way to improve light load engine efficiency.

Reviewer 6:
The reviewer noted that viable VCR concepts will provide improvements in fuel efficiency, although maybe not as much as claimed in this project (modeling 1-D results).

Reviewer 7:
The reviewer stated that as originally conceived, the project would result in an engine configuration (option) offering higher efficiency.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said funding is probably sufficient. This seems to be pretty much a one-man operation and any limitation by the PI could derail the project.

Reviewer 2:
The reviewer suggested to rescale to dyno and controls development for initial proof of concept funded appropriately.

Reviewer 3:
The reviewer stated that it is hard to say, the program looks thin in some areas for what has to be done, the reviewer's organization would not consider going in so blind into a technology program like this, the reviewer's organization would be making much more extensive use of analytical tools to support our design concepts and decisions. Such work does require money, but it saves it (in time alone) down the line.

Lean Miller Cycle System Development for Light-Duty Vehicles: David Sczomak (General Motors) - ace093

Presenter

David Sczomak, General Motors.

Reviewer Sample Size

A total of six reviewers evaluated this project.

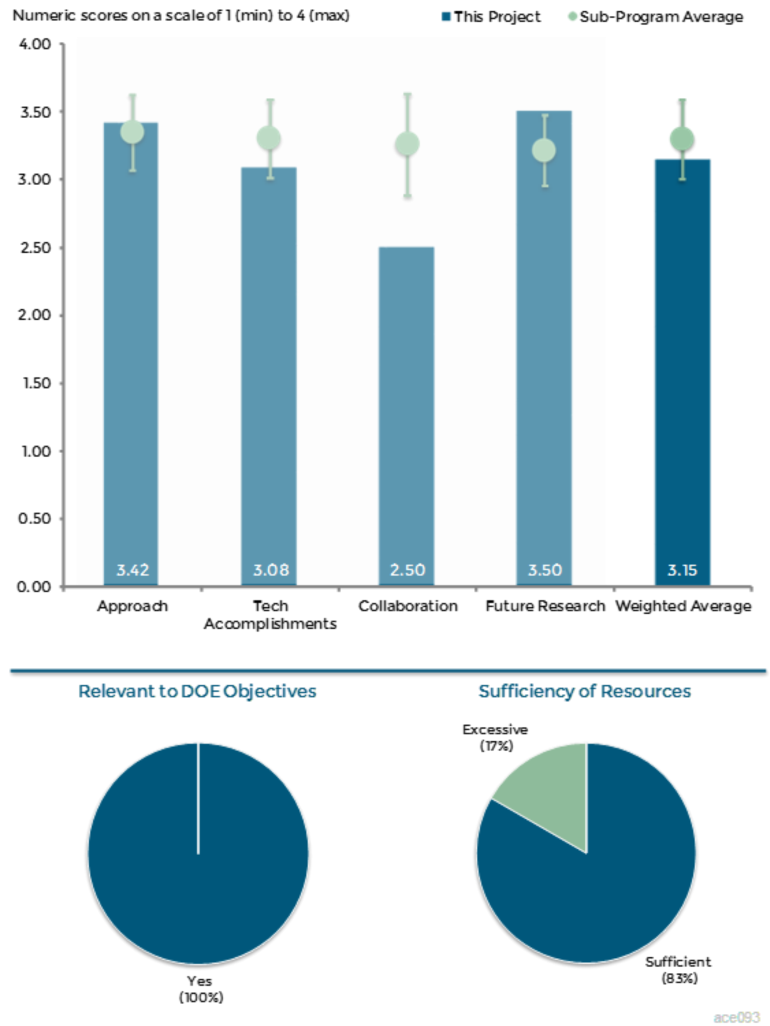

Figure 4-43 Lean Miller Cycle System Development for Light-Duty Vehicles: David Sczomak (General Motors) – Advanced Combustion Engines

Question 1: Approach to performing the work–the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that this new project has an excellent approach. The approach concentrates on high efficiency gasoline engine technology and will push the boundaries past existing state of the art with the Miller cycle and lean operation.

Reviewer 2:

The reviewer stated that while 35% FE improvement while meeting Tier 3 emissions is a challenging goal, an excellent approach with a detailed task plan was presented. A very good technical project plan with appropriate tasks, milestones and schedule was presented.

Reviewer 3:

The reviewer reported that lean burn in general is pushing it for the United States, and then downsized Miller cycle GDI will be a challenge. This is the kind of project that should be in these programs. The reviewer added that 25% fuel consumption (FC) improvements is big. The approach is classical with single cylinder engine (SCE), evaluation, MCE, vehicle. The reviewer also said it was good to farm out SCE to AVL, which has impressive experience in this realm.

Reviewer 4:

The reviewer said that some details of the approach came out in the Q&A that were not clear from the presentation, but insufficient detail was given to fully evaluate. This is early in the start of the project, and the team is still being assembled. The reviewer added that not all strategic partners/suppliers have been selected. AVL is being used for making single cylinder parts and testing of GM designs. The reviewer stated that without knowing the other strategic partners/collaborators, such as for the aftertreatment system, the soundness of the approach was difficult to evaluate.

Reviewer 5:

The reviewer commented that this project is still at a very early stage and there is sufficient time for course correction. It does not seem clear that the combination of lean-dilute combustion and passive/active SCR will be sufficient to achieve Tier 3 Bin 30 emissions. The reviewer explained that a lean-dilute approach will likely need some form of NO_x sorption to achieve the necessary cold-start NO_x control and lessons can be learned from use of this approach in ace061. Another, much simpler, approach would be dilute-stoichiometric using increased cEGR for dilution and conventional three-way catalyst control to achieve Bin 30. The reviewer suggested that there be some decision point partway through this project that could allow a course correction, if necessary, to assure that Bin 30 emissions are still within reach, similar to what occurred in ace065.

Reviewer 6:

The reviewer commented that this project concerns developing an ICE based on the Miller cycle. The PI believes this cycle has the capability to achieve DOE's target of a 35% improvement of engine efficiency. The approach seems to be to operate the Miller cycle to employ lean combustion. The reviewer added that the stated tasks include developing and demonstrating a vehicle, with testing of various cylinder heads to be done by AVL in a single cylinder engine. The Miller cycle has been known for decades (going back to the 1950s) and some manufacturers have commercialized engines based on it including Mazda, Subaru, etc. The presentation considered GM's effort to employing the Miller cycle in the context of the prior art. The reviewer said that it was not clear that a Miller cycle engine alone could facilitate achieving the targeted efficiency gain. Indeed, one of the presentation figures showed that an aggressive Miller cycle (aggressive was not defined) was projected to achieve an 18% improvement in efficiency. This is half of the target. The reviewer added that the other things that contribute to an efficiency improvement apparently are to come from elements that could be relevant to other parts of overall system and not specifically tied to developing a Miller cycle engine: 4% for advanced thermal management (not clear); 2% from friction/mass reduction. The reviewer asked what the specific strategy is and what the unique approach is here; 8% from downsizing; etc. In addition, the reviewer said the presentation was offered in vague terms with a long list of tasks, as if the audience already had a clear vision of what was needed to develop an engine based on the Miller cycle. Tasks like procure single cylinder hardware or multi-hole injection head design, or lean Miller development did not provide much information. Also, the reviewer commented that a large effort seemed to be associated with SCE testing of piston bowl designs. Curiously, no specific designs were shown, or how the overall system might be projected to respond to different designs. The reviewer asked if the piston bowl design is the key enabler to reaching the target. If so, the reviewer asked if the results of this effort could be used to develop a new piston bowl be applied to other engine concepts. The reviewer added that the CFD tool being employed was not clarified. The reviewer asked if it is KIVA, Converge, some other program. The reviewer also asked how will the codes be calibrated and assessed for accuracy. In addition, the reviewer asked what will be achieved with the simulations and what, specifically, do the PI's intend to do with simulation capabilities. Some 1-D modeling was mentioned but precisely what was to be modeled with such an approach was unclear.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the project management plan looks flexible and realistic. The scope and challenges are realistic. The reviewer said that expecting SCR+GPF is good for the plan. The project team can pull back if not needed. The reviewer added that thermal analyses seem aggressive, but give targets on what to work on for biggest bang.

Reviewer 2:

The reviewer said that as this is a new project, the technical accomplishments are in a state of development. The presentation did mention some computational efforts (1D and 3D modeling) and optimizing piston bowl design; however, details were not provided. The reviewer added that a lot of the effort seems to rely on SCE testing. The rationale for this was not clear from the presentation. The reviewer asked if there are there any concerns with extending results from a SCE to a MCE. The CFD work presented was interesting, but still hard to follow. It concerned a comparison between a CFD simulation (the code was not specified) of a spray calibration though the comparisons in the shown in one of the slides seemed mostly qualitatively correct in the CFD's ability to predict the spray pattern. The reviewer asked what would be done with this sort of capability (identify key features of the physics of the fuel injection... or ...analyze various piston bowls and spray shapes...) this should have been clarified.

Reviewer 3:
The reviewer commented that this project is a new start (only 5% complete) and therefore technical accomplishments are very limited (combustion modeling was initiated) and cannot be evaluated at this early stage.

Reviewer 4:
The reviewer indicated that no progress was reported, but to be fair, the slides were submitted just a few months after the project start.

Reviewer 5:
The reviewer thought that the approach to achieving 35% CAFE is fundamentally sound. The reviewer also thought some additional thought needs to be put into cold-start NO_x control.

Reviewer 6:
The reviewer stated that the project just beginning; so, not much to rank here. On track so far.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said the project team has got a world-class participant with AVL. The reviewer suggested that the project needs to line up others. GM has access to many suppliers, so the reviewer is not concerned.

Reviewer 2:
The reviewer indicated that while GM is an engine and vehicle OEM and AVL was identified as a project partner for engine component fabrication and experimental testing, the project could benefit by involving a national laboratory or a leading research university with appropriate core capabilities to increase and share the technical knowledge in this area. The reviewer added that it was acknowledged that suppliers for various engine components might be engaged from a strategic standpoint it would likely be beneficial to have the complete team onboard from the project start.

Reviewer 3:
The reviewer noted that only one other institution was identified, which was AVL. It was also unclear whether there was a contributing partner, or a supplier, but it seemed that supplier was the more appropriate term. The reviewer observed that additional strategic suppliers will be named as the project comes into full swing. Until these suppliers and the manner in which they will be used for the project are given, the collaboration and coordination cannot be highly rated. The reviewer added that this needs to be firmed up for next year's review.

Reviewer 4:
The reviewer commented that there really does not seem to be any collaboration with other institutions. AVL is a part of the team; however, their role appears to be more of a subcontractor. The reviewer also reported that getting other partners onboard was mentioned in the presentation.

Reviewer 5:
The reviewer thought that AVL is a good partner but the reviewer would like to see more collaboration with either the national laboratories or academia.

Reviewer 6:

The reviewer stated that one collaborator listed is AVL. The reviewer asked is this the only one. The milestone list indicates many external supplier organizations, but none are specified. The reviewer said that on this basis, the team would seem to still be in a state of development. It is not clear how the budget was developed with this level of uncertainty of the project team, especially if some key element of the project was based on an external supplier that could not provide the required services for the appropriate costs. The reviewer recommended that future presentations should clearly outline the partners, what they specifically bring to the project, and if and what are the budget allocations to them.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that a very detailed task plan was presented with appropriate quarterly milestones and annual go/no-go decision points. The project plan and schedule are appropriate for the project of this size ($20 million over 5 years) and with an aggressive goal of 35% FE improvement while meeting Tier 3 emissions standards (can be very challenging as the emissions control systems of today likely will not be adequate to achieve the required emissions levels).

Reviewer 2:

The reviewer noted that the future plan looks sound and the pathway to reach 35% improvement in FE meets the objective. The reviewer looks forward to seeing a more detailed plan presented in the future years.

Reviewer 3:

The reviewer stated that the plan was laid out, now execute. The reviewer thought many will be watching this project. A 25% FE reduction seems quite aggressive for lean burn GDI. The project team has identified the tasks quite well.

Reviewer 4:

The reviewer said that at this stage, virtually all the work is future work, but the plans are solid.

Reviewer 5:

The reviewer said again, this project is just beginning. In presenting the tasks for future work, these should be framed in a way that provides logic to the next steps needed to achieving the targeted efficiency levels; much was unclear here.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer remarked that this will directly reduce petroleum via engine efficiency gains for gasoline engines if successful. The gasoline-dominant U.S. fleet means the relevance is high.

Reviewer 2:

The reviewer explained that efficiency improvements in LD powertrain (35% FE improvement target) result in lower fuel use and therefore a direct displacement of petroleum for passenger vehicles.

Reviewer 3:

The reviewer commented that 25% FE is certainly in line with DOE objectives. As a taxpayer, the reviewer likes these projects that push the envelope through established parties. The money is well spent.

Reviewer 4:
The reviewer stated that 35% improvement in FE for LD vehicles will reduce petroleum consumption in the transportation sector.

Reviewer 5:
The reviewer said that of course, any project that could achieve the targeted 35% efficiency gain would be considered relevant. For this project, there is not sufficient resolution in the question (yes or no' is too coarse) to answer. For the time being, the answer is presumably yes.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that this is a high importance and visibility project due to the aggressive goal of fuel efficiency improvement (diesel-like efficiency) and emissions reductions; therefore the $20 million project budget with $8 million DOE share is very appropriate.

Reviewer 2:
The reviewer noted no need to change at this stage. Big project, but big challenges.

Reviewer 3:
The reviewer stated that on the surface, the allocated funds for this project ($8 million from the government) seems a bit excessive, because much seems to be in a state of flux. Presumably, there would be costs associated with having external suppliers providing services or goods. The reviewer added that it would seem that some element of budgetary scrutiny is appropriate given that some details of the project team were not provided in the presentation.

Ultra-Efficient Light-Duty Powertrain with Gasoline Low-Temperature Combustion: Keith Confer (Delphi Powertrain) - ace094

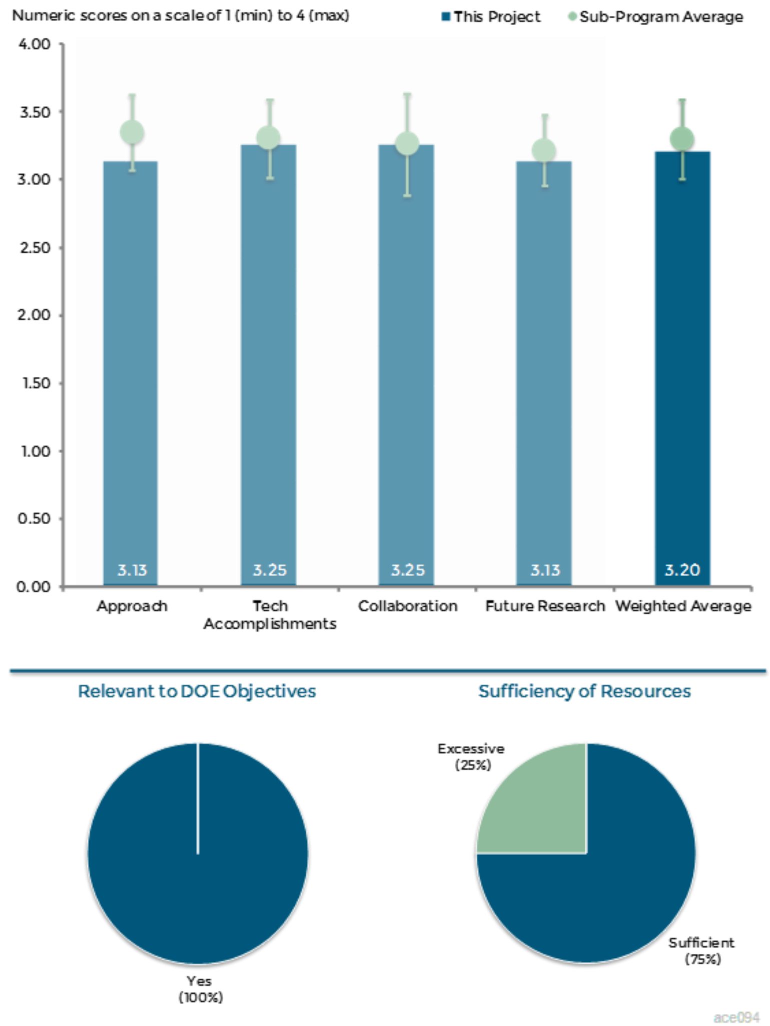

Figure 4-44 Ultra-Efficient Light-Duty Powertrain with Gasoline Low-Temperature Combustion: Keith Confer (Delphi Powertrain) – Advanced Combustion Engines

Presenter

Keith Confer, Delphi Powertrain.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that while 35% FE improvement while meeting Tier 3 emissions is a challenging goal, a good approach was presented leveraging DOE ATP1 Delphi project award (2008-2013) to setup DOE ATP2 (this project) for success with strong partner expertise. Very good technical project plan with appropriate tasks, milestones and schedule was presented.

Reviewer 2:

The reviewer reported that the approach is traditional: SCE, generation 1 (Gen 1) MCE, generation 2 (Gen 2) MCE, simulation, emissions, and vehicle. Gasoline direct compression engine (GDCI) is a good combustion strategy to go after; Lund, Aramco, UW, Delphi, and Argonne National Laboratory are all working on it.

Reviewer 3:

The reviewer stated that this project is connected to efforts that began in 2008 which explored the viability of GDCI. That effort apparently resulted in an engine (to be used for the present project) with a vehicle that exceeded the targeted 35% efficiency limit for combined highway/city economy improvement with a warmed up engine. That vehicle/engine did not; however, appeared to not satisfy emissions performance targets, hence the present project. The reviewer added that the focus of this project is, therefore, to work to reduce harmful emissions while not sacrificing FE. The PI notes that the current effort will leverage the hardware developed from the prior effort with a new team with a focus on vehicle emissions. The engine platform will apparently be the same. The reviewer also said that the project is interesting but a rationale for the approach is lacking. A list of tasks is presented, for example, vehicle characterization, single cylinder engines, multi-cylinder engines, dynamometer testing, catalyst evaluation, debugging the single and multi-cylinder Gen2 engine developed in the first project, etc., but it was never clear precisely how the tasks would address emissions without also potentially influencing efficiency. The presentation indicated that “combustion efficiency as well as aftertreatment will be used to address emissions," which is fair enough, but not quantitative from the reviewer's perspective. The tasks were presented in the broadest terms.

Reviewer 4:

The reviewer did not see a strategy clearly articulated regarding how the Tier 3 emissions targets would be met and that was part of the milestones for 2014. The reviewer thought that this project could really benefit from closer coordination with Umicore on integrating the combustion and emissions control system strategies.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer observed that 28% FC reduction versus baseline is very impressive for Gen 1. More improvements coming with Gen 2 engine. The project is poised for progress, building project infrastructure. The reviewer added that impressive work on friction is a good example of how Gen 2 will improve over Gen 1. Relative to other similar GCI, it seems the project team is ahead.

Reviewer 2:

The reviewer said that this project was a new start (2014) but leveraging previous DOE ATP1 project work that showed potential for 39% FE improvement with similar gasoline direct injection compression ignition concept. This was accomplished at warmed up condition and did not meet Tier 2 Bin 2 goals of previous project. The reviewer added that a Gen2 engine setup (built outside of DOE funded project with HATCI) and simulations have been completed (first two milestones accomplished). Gen 1 development engines met full load MCE torque needs (20 bar peak) in dynamometer tests. The reviewer said that significant firing and motoring friction reduction results from Gen2 engine were also presented.

Reviewer 3:

The reviewer indicated that the project has made some gains. A vehicle is in place from the UFEV project and it is outfitted with a range of equipment. Some data show emission transients and new algorithms (not discussed) were developed to improve transient control; the algorithms are being calibrated. The reviewer added that a Gen2 engine was designed outside of DOE funded projects, and operated to evaluate injection strategies which is vague because the reviewer asked what the quantitative link is between 'injection strategies and efficiency or emission. The PI's team mounted their Gen2 engine on a dynamometer and is ready for testing, and all this may be good. The reviewer explained that the problem is that, as presented, it appeared like a disconnected collection of tasks. The PI needs to bring more focus to each of the tasks and better make the case for the necessity of the individual efforts.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that the project team has got some of the best. UW, Umicore, ORNL, and Hyundai. The reviewer added that it seemed that everyone is engaged. The project team needs to collaborate with the others working on this technology, ANL, Lund, others. The reviewer also stated that these partners likely have experiences and knowledge the project team can use. All these parties have vested interests in your project.

Reviewer 2:

The reviewer stated that the project team includes several industries, a national laboratory and a university. The role of each of these groups needs better focus. The reviewer added that for ORNL, their task is to analyze emissions samples; Hyundai is to develop and engineering design; UW is to perform characterization testing of gasoline fuel injectors; while Umicore will prepare low temperature exhaust samples. This is all good. The reviewer explained that what is missing is an interconnectedness and coordination that justifies the necessity for the deliverables which the collaborators will provide. For example, if the university partner is to characterize fuel injectors, the reviewer asked if the results will be used, what type of fuel injectors are used, and if these results are novel, or off-the-shelf, etc..

Reviewer 3:

The reviewer commented that the team is led by a large domestic Tier 1 supplier, supported by a vehicle OEM, emissions control manufacturer, DOE national laboratory with emissions core competency, and a leading combustion research university. ORNL emissions, HATCI, the OEM carryover from DOE ATP1 project, engine manufacturing, UW at Madison fuel injection characterization, and Umicore aftertreatment expertise makes a very good team. The reviewer added that there was appropriate and integrated team roles and responsibilities with proven previous collaboration experience.

Reviewer 4:

The reviewer noted that nothing was said about emissions control system hardware or integration of combustion strategy with strategies for HC and/or NO_x storage for cold start or about PM control. Tier 3 has very aggressive non-methane organic gas/ NO_x and US06 PM requirements.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the project team had a good plan to refine the combustion, integrate emission control, and work on transients. Emissions issues will be key, but the reviewer is not too concerned, yet. Keep driving efficiency. The reviewer added that when emissions issues get critical, one may want to take a look at an engineering solution without compromising efficiency, pre-turbo oxidation catalyst. Turbo lag is addressed with supercharger and/or mild hybrid. The reviewer also said that this will also help keep the EGR cooler clean. Given this is a huge step-change in technology, one may as well go all the way

Reviewer 2:

The reviewer observed that the project team had an aggressive FE goals (35% improvement, diesel like efficiency) but building upon good results from a previous project, DOE ATP1. Developing a new low-temperature emissions aftertreatment system to achieve Tier 3 standards will be a significant challenge, the Tier 2, Bin 2 target of a previous project, was not met. Since the project is only six months into a four year schedule, as of AMR presentation submission, the proposed future work remains significant but seems appropriate.

Reviewer 3:

The reviewer reported that a challenge going forward is the development of an aftertreatment system commensurate with the highly efficient engine the group has developed, this is fine; however, it does not tell us much about the steps that are needed to improve the state of the art on aftertreatment concepts. The reviewer asked what fuel injectors are being tested. The reviewer then asked what is unique about them. The reviewer then asked what injector types are being tested. The reviewer also asked what their designs are. In addition the reviewer asked why these types are deemed attractive for meeting project goals. The importance of the plan going forward was evident in only the broadest terms who can argue that an aftertreatment system that is effective in dealing with a highly efficient engine would not be beneficial, but the reviewer asked what will be the strategy for developing this system, and therefore, much was vague.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer commented that the technology shows the best promise of DOE powertrain development to reduce fuel consumption. Diesel level efficiency with gasoline fuel.

Reviewer 2:

The reviewer said that this is a relevant project. The PI already has an engine that is efficient. The reviewer explained that what is needed is more effort to reduce its emissions, which apparently is the work of this project, though much of the approach was not clear.

Reviewer 3:

The reviewer stated that efficiency improvements in LD powertrain, or 35 % FE improvement target, result in lower fuel use and therefore a direct displacement of petroleum for passenger vehicles.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that this is a high importance and visibility project due to the aggressive goal of FE improvement (diesel like efficiency) and emissions reductions; therefore the nearly $10 million DOE budget share is very appropriate.

Reviewer 2:

The reviewer said large project, but good progress. Public funding seems suitable.

Reviewer 3:

The reviewer commented that at first impression, based on the information provided in the presentation, is that the provided resources are excessive. DOE is providing almost $10 million total to this project, where there was $3 million in 2015. The reviewer added that the PIs already have a gen2 GDCI engine developed outside of DOE funded projects. This new project that focuses on emissions controls now requires a government investment of $10 million. The reviewer also said that given that the PIs already have an engine it was not evident that a focus on emissions warranted such an expenditure, at least from what was presented. If the PIs feel otherwise, it would be appropriate to at least provide broad indications of what various project costs are. It was lack of clarity/information provided in the presentation that lead to this assessment as much was presented in only the broadest terms.

Metal Oxide Nano-Array Catalysts for Low-Temperature Diesel Oxidation: Pu-Xian Gao (University of Connecticut) - ace095

Presenter

Pu-Xian Gao, University of Connecticut.

Reviewer Sample Size

A total of five reviewers evaluated this project.

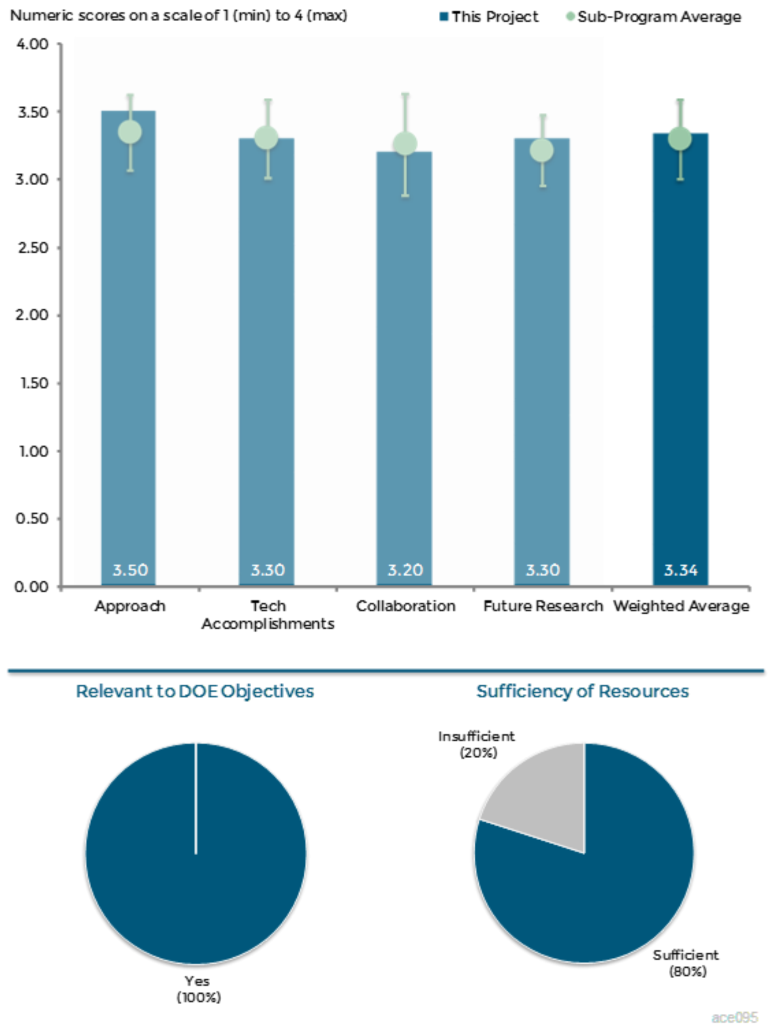

Figure 4-45 Metal Oxide Nano-Array Catalysts for Low-Temperature Diesel Oxidation: Pu-Xian Gao (University of Connecticut) – Advanced Combustion Engines

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that this is an exciting project because it uses a totally different approach to synthesizing the catalyst and applying it to the substrate. Wash coating produces an amorphous coating which is always being analyzed for the composition at the surface. The reviewer added that this approach is very clear as to the composition at the surface because it is being grown epitaxial.

Reviewer 2:

The reviewer remarked outstanding novel approach to grow and characterize nano-arrays on monolith with and without PGM using potentially scalable methods including solution and gas phase approaches. The reviewer added that a solid consideration of needs and requirements driven from the U.S. DRIVE The 150ºC Challenge Workshop Report, and 2013 U.S. DRIVE ACEC Technical Team Roadmap; lower temperature CO oxidation; HC oxidation; and NO_x reduction, reduced PGM, and better thermal aging stability.

Reviewer 3:

The reviewer reported that it is very important for this approach to show that there is sufficient surface area to carry out the reaction in real exhaust. So the testing criteria needs to be well spelled out as targets for known/reference catalysts and then these new catalysts. The reviewer added that a very wide range of materials has been chosen considering the time for the contract. Inclusion of ORNL team in project is also a key to the approach being kept focused on what may work in real catalyst systems.

Reviewer 4:

The reviewer commented that in general, this use of rare-earth and base metals as a substitute for precious metals is a novel approach to address very early inception stage research for the discovery of materials active for low-temperature CO oxidation; however, the conditions employed throughout the research project to date are far from those necessary to eliminate technologies early in the testing process. The reviewer added that the appropriate test conditions that include known CO and HC reaction inhibitors at low-temperature were not used in the screening process. Also, using aging conditions that will be experienced by these materials in their intended application were not widely used as a probe of activity and stability of the material. The reviewer added that using these variables as probes of activity will probably have saved considerable time to determine the viability of this technology.

Reviewer 5:

The reviewer said it would help to provide a definition of nano-array for those of us who are unfamiliar with this technology. Need to show effects of thermal aging on the activity for all of the catalysts, like the presenter did for the Pt/titanium oxide, or TiO_2, catalysts (for example, show light off performance before and after aging). The reviewer added that a catalyst needs to be able to tolerate at least 800°C with up to 10% H_2O in the exhaust.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer pointed out that there were excellent accomplishments demonstrating capability to grow and test PGM-free nano-array catalysts such as spinel $MxCo_3 - xO_4$, when M=Co, Ni and Zn. Zn-based data shows strong promise at 90% conversion of propane and 85% of CO at 350°C. The reviewer added that further promising results from samples with 0.3 weight Pt loaded TiO_2 and TiO_2-Al_2O_3 nano-array monoliths which resulted in 80% propane conversion at 250°C and some improved aging with TiO_2-Al_2O_3.

Reviewer 2:

The reviewer stated that coating on a monolith and doing the activity measurements are great accomplishments. The high water sensitivity and sulfur sensitivity is very disturbing even though the epitaxial growth methodology is great.

Reviewer 3:

The reviewer observed that the results with the NiCo catalysts were impressive and promising, particularly for C_3H_8 (propane) conversion. Again, the team needs to define the test conditions better, in regards to gas concentrations, space velocity, aging, etc.. The reviewer added that it would be good to include the results for a representative three-way catalyst to compare to the results for the NiCo and Co catalysts. It was unclear to this reviewer why the performance of the mesoporous Co_3O_4 catalyst fell off suddenly at 11 hours or so on Slide 14. The reviewer asked what regeneration means on the graph. The reviewer asked what does Meso-Mn-AR and Meso-Mn-HC mean on Slide 15. The reviewer said the perovskite catalysts looked to be a long way from a light-off temperature of 150°C. The reviewer asked if there is a reason to continue developing them. The Pt/TiO_2 conversions were good, especially with the alumina-stabilized titanium. The reviewer added that it is good to age the catalysts at 800°C as the project team did, as that is a minimum temperature for durability whether it is for diesel catalysts or for the underbody catalyst on a gasoline engine.

Reviewer 4:

The reviewer reported that very good progress was made in the characterization of multiple catalyst formulations using base test conditions. The HC species used were appropriate and represented challenging molecules to convert at low-temperature; however, using a growth technique to deposit an active catalyst material on a substrate may preclude the adoption of this technology. The reviewer added that manufacturability is a critical element to both OEMs and catalyst manufacturers. If the process to create the catalyst requires too production time and or cost, the likelihood of using this material is low. Therefore, the reviewer said that when developing an aftertreatment technology, both appropriate test conditions and manufacturability are key aspects to address before significant resources are employed for the project work.

Reviewer 5:

The reviewer commented that the growth of a number of samples has been accomplished along with catalytic characterization. The number of systems on the to-do list is large. It could be better to focus on the most promising and needed materials, even if others are easier to work with. The reviewer also stated testing of materials grown on the cordierite should include how the reactive surface area increases with added mass. There may be an optimum below the biggest mass. Also, the survival of the new growth in strong vibrations or sharp collisions should be tested.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said there was excellent collaboration with national laboratories, a catalyst manufacturer, and novel nano-structure company.

Reviewer 2:

The reviewer reported that collaborations are sufficiently broad, with a full ORNL and Umicore involvement. These, particularly Umicore, should be useful, again to keep the evaluations realistic.

Reviewer 3: .

The reviewer stated that collaboration with ORNL and Umicore was mentioned along with Brookhaven National Laboratory.

Reviewer 4:

The reviewer commented that inclusion of an OEM or wash coat supplier to help determine the viability of the material and production process at an early stage would have benefited this project.

Reviewer 5:

The reviewer observed some evidence for collaboration with ORNL; however, it seems to be mostly professional advice, but that is clearly a step forward.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that there was an excellent map for future with metal oxide nano-array catalysts designed for: performance at 150°C or lower, optimized PGM loading with perovskite nano-particles, CO and HCs oxidation tests under simulated exhaust atmosphere, and engine testing in FY 2016. There is a possibility for future work inside or outside the effort with high potential once aging is confirmed is collaboration for nano-arrays deposition on exhaust sensors.

Reviewer 2:

The reviewer said that reasonable choice of future studies has been made. Down selection, as mentioned already, should be considered, because of the breadth of catalyst families in the program.

Reviewer 3:

The reviewer commented that the project team is proceeding down this pathway; however, there is no specific approach to mitigate the water and sulfur problems.

Reviewer 4:

The reviewer stated that the future work to address aging and environmental effects on the CO and HC activity of these materials is appropriate, but should have been employed at an earlier stage.

Reviewer 5:

The reviewer said that there is a need to include realistic aging conditions in all catalyst development. Fresh performance is not sufficient. The reviewer added that the project team needs to explore sulfur tolerance and desulfation capability of the more promising candidates. 2016 is probably premature for engine testing. The reviewer also stated that there is a lot of work to do to demonstrate low-temperature activity and durability on a lab reactor before proceeding to engine testing. The reviewed remarked that one has to walk before one can run.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer commented that low Pt and/or low temperature catalysis are major goals for the DOE. This project attacks both of these goals.

Reviewer 2:

The reviewer stated that this project supports U.S. Council for Automotive Research (USCAR)/U.S. DRIVE initiatives to address the need for low-temperature aftertreatment to produce viable solutions for emerging, higher efficiency combustion strategies.

Reviewer 3:

The reviewer reported that with the right results energy use should drop during cold start.

Reviewer 4:

The reviewer observed that the low-temperature catalysts will be needed for more efficient engines in the future that produce lower exhaust temperatures.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that with initial proof of concept success at full scale catalyst size and vetting of potential for production volume application, additional partners and funding could significantly improve the time to production impact of this outstanding approach and preliminary result.

Reviewer 2:

The reviewer stated that this project is appropriately funding, but a wash coat supplier should have been consulted or used to help direct the research activities.

Reviewer 3:

The reviewer said that the resources appear to be sufficient.

Acronyms and Abbreviations

1D	One dimensional
3D	Three dimensional
ACE	Advanced combustion engine
ACEC	Advanced Combustion and Emissions Control
AEC	Advanced Engine Combustion
AFCI	Advanced Fuel Cycle Initiative
AFR	Air to fuel ratio
AKI	Anti-Knock Index
AMR	Annual Merit Review
ANL	Argonne National Laboratory
APS	Advanced photon source
ARRA	American Recovery and Reinvestment Act
Au	Gold
AVFL	Advanced Vehicle/Fuel/Lubricants
BES	DOE Basic Energy Sciences
BMEP	Brake Mean Effective Pressure
BP	Bandpass
BSFC	Brake-specific fuel consumption
BSG	Belt-Driven Starter-Generator
BTE	Brake Thermal Efficiency
C	Centigrade
Ca	Calcium
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
CCC	Co-precipitated CuOX, CoOy, and Ceo2 catalyst
CCV	Cycle-to-cycle variability
CDC	Conventional diesel combustion

CFD	Computational Fluid Dynamics
CH4	Methane
CHA	Chabazite
CI	Compression Ignition
CLEERS	Cross-Cut Lean Exhaust Emissions Reduction Simulations
CNT	Carbon Nanotubes
CO	Carbon Monoxide
CO2	Carbon Dioxide
COV	Coefficient of variance
CPU	Central processing unit
CR	Compression Ratio
CRF	Combustion Research Facility
CRADA	Cooperative Research and Development Agreement
CRC	Coordinating Research Council
CSC	Cold Start Concept
CT	Computed tomography
Cu	Copper
CZ	Ceria-zirconia
dBA	Decibel
D-EGR	Dedicated-Exhaust Gas Recirculation
DC	Direct current
DI	Direct Injection
DISI	Direct Injection Spark Ignited
DOC	Diesel oxidation catalyst
DOD	U.S. Department of Defense
DOE	Department of Energy
DNS	Direct numerical simulation
DPF	Diesel particulate filter

DRG	Diagnosis-related group
DSNY	City of New York Department of Sanitation
DTBP	Di-t-butyl peroxide
E0	0% ethanol blend with gasoline
E10	10% ethanol blend with gasoline
E20	20% ethanol blend with gasoline
E85	85% ethanol blend with gasoline
EATS	Exhaust after-treatment system
ECN	Engine Collaboration Network
ECS	Emission control system
ECU	Engine control unit
EGR	Exhaust Gas Recirculation
EHN	2-ethylhexyl nitrate
EHR	Exhaust heat recovery
EPA	U.S. Environmental Protection Agency
ERC	Engine Research Center
FA	Field Aging
FACE	Fuels for Advanced Combustion Engines
FE	Fuel Economy
FEA	Finite element analysis
FGM	Flamelet generated manifold
FMEP	Friction mean effective pressure
FST	Filter sensing technologies
FTP	Federal Test Procedure
FTIR	Fourier Transform Infrared Spectroscopy
FY	Fiscal year
g	gram
GCI	Gasoline compression ignition

GDI	Gasoline Direct-injected
GDCI	Gasoline Direct Compression Engine
GE	General Electric
GFR	Glomerular filtration rate
GHG	Greenhouse gas
GM	General Motors Corporation
GPF	Gasoline Particulate Filter
GPU	Graphics Processing Unit
GSA	Global sensitivity analysis
GTDI	Gasoline Turbocharged Direct Injection
H2	Hydrogen
H2O	Water
HC	Hydrocarbon
HCCI	Homogeneous Charge Compression Ignition
HCl	Hydrogen chloride
HD	Heavy-Duty
HECC	High efficiency clean combustion
HEDGE	High-Efficiency Dilute Gasoline Engine
HPC	High Performance Computing
HV	High voltage
ICE	Internal Combustion Engine
ICT	Institute of Chemical Technology
IDT	Ignition delay times
IMEP	Indicated Mean Effective Pressure
IP	Intellectual property
IR	Infrared
ISFC	Indicated Specific Fuel Consumption
ITE	Indicated Thermal Efficiency

K	Potassium
Kn	Knudsen Number
L	Liter
La	lanthanum
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LD	Light-Duty
LDA	Laser doppler anemometry
LES	Large Eddy Simulation
LEV	Low Emission Vehicle
LIF	Laser-induced fluorescence
LLNL	Lawrence Livermore National Laboratory
LNT	Lean NOx Trap
LPL	Low-pressure loop
LT	Low temperature
LTC	Low Temperature Combustion
LTGC	Low Temperature Gasoline Combustion
MBC	Model based controls
MCE	Multi-cylinder engine
MD	Medium-Duty
Mg	Magnesium
MIT	Massachusetts Institute of Technology
mJ	Millijoule
Mn	Manganese
MOU	Memorandum of Understanding
MPG	Miles Per Gallon
ms	Milliseconds
MSU	Michigan State University

MTU	Michigan Technological University
N2	Nitrogen
N2O	Nitrous Oxide
NA	Naturally aspirated
NG	Natural gas
NH3	Ammonia
NIST	National Institute of Standards and Technology
NMOG	Non-methane organic gases
NO	Nitric Oxide
NOx	Oxides of Nitrogen
NO2	Nitrogen Dioxide
NREL	National Renewable Energy Laboratory
NSC	NOx Storage Catalyst
NSF	National Science Foundation
NSR	NOx Storage Reduction
NVH	Noise, vibration, and harshness
NVO	Negative Valve Overlap
O2	Oxygen
OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
OH	Hydroxide
ORC	Organic Rankine Cycle
ORNL	Oak Ridge National Laboratory
OSC	Oxygen storage capacity
OSU	Ohio State University
PAH	Polycyclic aromatic hydrocarbon
PCCI	Premixed Charge Compression Ignition
PDT	Pulse discharge technique

PFI	Port Fuel Injection
PFS	Partial fuel stratification
PGM	Platinum group metal
PI	Principal Investigator
PIV	Particle image velocimetry
PM	Particulate matter
PN	Particulate number
PNA	Passive NOx adsorber
PNNL	Pacific Northwest National Laboratory
POD	Proper orthogonal decomposition
PPC	Partially Premixed Combustion
ppm	Part per million
Pr	Praseodymium
Pt	Platinum
PWM	Pulse width modulation
R&D	Research and development
RANS	Reynolds-Averaged Navier Strokes
RCCI	Reactivity Controlled Compression Ignition
RCM	Rapid compression machines
RF	Radio frequency
Rh	Rhodium
ROI	Return on investment
RON	Research octane number
SACI	Spark assisted compression ignition
SAE	Society of Automotive Engineers
SCR	Selective Catalytic Reduction
SCRF	Selective catalytic reduction on filters
SEM	Scanning electron microscope

SI	Spark-ignition
SIDI	Spark-ignition direct-injection
SMD	Sauter Mean Diameter
SNL	Sandia National Laboratories
SOF	Solvent extractable fraction
SULEV	Super Low-Emission Vehicle
SUV	Sport utility vehicle
TARDEC	U.S. Army Tank and Automotive Research, Development and Engineering Center
TCR	Thermochemical recuperation
TDC	Top dead center
TE	Thermoelectric
TEG	Thermoelectric Generator
TJI	Turbulent jet ignition
TRD	Transmission radiation detector
TWC	Three-Way Catalyst
UC	University of California
UConn	University of Connecticut
UHC	Unburned hydrocarbons
UM	University of Michigan
UQ	Uncertainty quantification
USCAR	U.S. Council for Automotive Research
U.S. DRIVE	U.S. Driving Research and Innovation for Vehicle Efficiency and Energy sustainability
UW	UW
UWM	UW-Milwaukee
VCR	Variable compression ratio
VCT	Variable camshaft timing
VTO	Vehicle Technologies Office
VUV	Vacuum ultraviolet

VVA	Variable Valve Actuation
WHR	Waste Heat Recovery
WSU	Washington State University
XAFS	X-ray absorption fine structure
XPS	X-ray photoelectron spectroscopy
Zr	Zirconium
ZT	Thermoelectric Figure of Merit

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