1. Advanced Combustion Systems

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Office (VTO) funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. VTO leverages the unique capabilities and world-class expertise of the national laboratory system and works with partners across industry and academia to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. VTO is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus U.S. Department of Energy (DOE) research on the most critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry either does not have the technical capability to undertake on its own— usually because there is a high degree of scientific or technical uncertainty—or it is too far from market realization to merit sufficient industry emphasis and resources.

The Advanced Combustion Systems (ACS) subprogram supports early-stage R&D to improve our understanding and ability to manipulate combustion processes, fuel properties, and catalyst formulations. This generates the knowledge and insight necessary for industry to develop the next-generation of engines and fuels for light-duty (LD) and heavy-duty (HD) vehicles. As a result, co-optimization of higher-efficiency engines and high performance fuels has the potential to improve LD fuel economy by 35% (25% from advanced engine research and 10% from co-optimization with fuels) by 2030 compared to 2015 gasoline vehicles. The subprogram supports cutting-edge research at the national laboratories, in close collaboration with academia and industry, to strengthen the knowledge base of high-efficiency, advanced combustion engines, fuels, and emission control catalysts. The ACS subprogram utilizes unique facilities and capabilities at the national laboratories to create knowledge, new concepts and research tools that industry can use to develop advanced combustion engines and co-optimize with fuels that will provide further efficiency improvements and emission reductions. These unique facilities and capabilities include the Combustion Research Facility (CRF) at Sandia National Laboratories (SNL), Advanced Photon Source at Argonne National Laboratory (ANL), Institute for Integrated Catalysis at Pacific Northwest National Laboratory (PNNL), detailed fuel chemistry expertise at the National Renewable Energy Laboratory, chemical kinetic modeling and mechanism development at Lawrence Livermore National Laboratory (LLNL), and the Spallation Neutron Source at Oak Ridge National Laboratory (ORNL), along with their high-performance computing (HPC) resources and initial work to utilize future exascale computing resources.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2018 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

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.

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.

Presentation Number: acs918
Presentation Title: Advanced Combustion Systems and Fuels R&D Overview
Principal Investigator: Gurpreet Singh, U.S. Department of Energy

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

Reviewer 1:
The reviewer remarked that the program area was adequately covered and well described. This reviewer further recounted several items shown by the presenter: doubling of power density in ten years as related to engine trends; fuel economy increases as vehicles get larger; and regarding emissions trends, emissions have gone down while the number of vehicles and vehicle miles traveled have increased. The reviewer added that technologies to help the trend, which shows technology penetration, include gasoline direct injection (GDI); turbochargers (used with GDI); cylinder deactivation (CD); engine stop/start; transmissions (six or more speeds); continuously variable transmissions. Overall, the reviewer commented that the program has been successful and continues to be successful due to industry, academic, and government collaboration.

Reviewer 2:
This reviewer asserted that the strategy of Advanced Combustion Systems and Fuels R&D to reduce fuel consumption and emissions through higher efficiency and cleaner combustion-based power was clearly described. Further, the reviewer observed that a clear explanation of the impact of combustion-based vehicle power on the environment was also covered.

Reviewer 3:
This reviewer indicated that yes, the program area and overall strategy are well covered.

Reviewer 4:
This reviewer stated yes.

Reviewer 5:
The reviewer responded positively and observed brief but complete coverage of the program area, including overall strategy. The reviewer added that strategy was well described and seems very good.

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

Reviewer 1:
The reviewer affirmed that both near- and long-term R&D are balanced to achieve the overall R&D goals of the program.

Reviewer 2:
This reviewer responded positively; the work with industry affects near-term effectively. There is solid long-term science that greatly contributes to advancing engine knowledge and technology.

Reviewer 3:
The reviewer explained that the program looks at mid-term (advanced spark ignition [SI] research) and long-term (low temperature combustion [LTC] research), fuel and fuel property effects, and aftertreatment for all combustion types. The reviewer continued that this balance is beneficial to the original equipment manufacturers (OEMs) and is well endorsed by them.

Reviewer 4:
This reviewer responded yes, and noted that a recent update to the Advanced Combustion and Emissions Control (ACEC) roadmap with priorities is integrated into plans. The reviewer also highlighted mixed mode for LD long-term and boosted SI for near-/mid- LD.

Reviewer 5:
The reviewer stated yes.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer commented that yes, the goals were well defined and developed with industry collaboration. Generally, this reviewer described the goals as a significant improvement in engine efficiency while maintaining low emissions and acceptable performance. The presenter showed how the research is successfully approaching these goals.

Reviewer 2:
The reviewer stated yes; it was good to see slides showing the amount of oil saved by investing in internal combustion engines (ICEs). This reviewer further commented that ICE is clearly shown to be relevant long-term.

Reviewer 3:
This reviewer commented that yes, the issues impacting current and future combustion-based vehicles were clearly identified and the challenges to meet future efficiency and emissions goals were adequately described.

Reviewer 4:
The reviewer responded positively and further commented that the challenges were identified and related to the overall system issues.

Reviewer 5:
This reviewer stated yes

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

Reviewer 1:
The reviewer reported that the presenter showed the areas of research that the program focusses on, the proposed research road map to reach the goals, and the technologies of focus that will allow that from fuels to engine parts to combustion systems to energy recovery systems to aftertreatment. This is a well thought out program that exemplifies how government and industry collaboration can benefit the United States as a whole.

Reviewer 2:
The reviewer replied yes; plans for developing enabling technologies for cleaner and more efficient combustion engines and fuels are clearly identified and outlined.

Reviewer 3:
The reviewer responded positively and added that plans seem solid and well thought out.

Reviewer 4:
This reviewer stated yes.

Reviewer 5:
This reviewer indicated yes and noted that the emission control R&D slide could have also included challenges of cold start and catalyst light-off.

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

Reviewer 1:
This reviewer stated yes; the targets are carefully developed with industry input and are recently updated. The reviewer described goals as aggressive, but not unreasonable.

Reviewer 2:
The reviewer expressed that it is difficult to gauge progress on such a fine year-by-year timescale for such a large endeavor. However, this reviewer observed that year-to-year trends over the long haul are covered very adequately.

Reviewer 3:
This reviewer referenced an original baseline that had been changed to a more recent engine. The reviewer further commented that the program was benchmarked against the previous year and prior years. The changing baseline made the gains look smaller, but the reviewer explained this is well thought out because it gives a better technological baseline to compare against future research. The reviewer opined that the Program Manager should be commended for making this change because it will give honest, but not inflated, improvements.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer commented that some information was presented.

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 indicated yes; the projects seem well chosen to drive transportation technology in useful and effective directions.

Reviewer 2:
The reviewer explained that this program is focused on solving the technological barriers that the VTO office is trying to solve. The projects deal directly with improving the fuel consumption of engines and lowering the energy demands of vehicles.

Reviewer 3:
This reviewer responded positively and asserted that projects like SuperTruck II and Co-Optima are definitely addressing the "broad problems" that VTO is attempting to solve.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer replied yes, to some degree. With respect to Co-Optima, the reviewer commented that near-/mid-term fuel for dilute downsized boosted SI should be the same fuel as that for longer-term mixed mode combustion.

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

Reviewer 1:
The reviewer responded positively and was quite impressed with the leadership team, who are effective in leading a collaborative program. The leadership team's history and expected future are examples of how government should work to improve society.

Reviewer 2:
This reviewer described the program as focused, well managed, and effective. Overall engine efficiency has increased significantly. The reviewer further explained that, thanks to this program, overall understanding of LTC concepts have gone from a science experiment to commercially viable (during parts of the engine map), and low-temperature aftertreatment (LTAT) that did not look possible now appears to be on the horizon.

Reviewer 3:
The reviewer asserted that the program area is very focused, well managed, and generally effective.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer stated yes.

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 asserted that all of the projects are well run and very strong.

Reviewer 2:
This reviewer commented that the program is extremely strong in all technical areas of need. The program manager is good at getting collaboration for industry and academia and it shows in the areas of research and research results. The only weakness observed by the reviewer was that the academic participation, while significant, was not as strong as the industry participation.

Reviewer 3:
The reviewer highlighted close involvement with industry, university, and lab teams as a strength. Further, this develops collaborative efforts toward major technical barriers. This reviewer also noted consideration of both LD and HD segments requirements. The reviewer described the tendency to emphasize collaboration to an extent that the overhead of coordination can become significant as a weakness.

Reviewer 4:
Key strengths observed by this reviewer include engagement of wide-range of resources from government laboratories, academia, and industry to tackle problems via a variety of projects and working groups. The reviewer commented that the program area actively seeks out and engages stakeholders to ensure that research remains focused on what all agree is important. However, coordination between labs and leveraging of their different strengths, while much better today than just a few years ago, could still be improved upon, as could encouragement of collaborative research projects between these labs and industry. The reviewer suggested that improved paths towards implementation of government-created tools and methodologies in the commercial sphere should be created and streamlined. Forums like Cross-cut Lean Exhaust Emissions Reduction Simulations (CLEERS) and Advanced Engine Combustion (AEC) memorandum of understanding (MOU) are excellent examples of ways to share DOE learning with industry and how to provide a feedback mechanism to guide future research so that it remains relevant. The reviewer further indicated that projects like Co-Optima show a degree of coordination between the national laboratories that was sadly lacking just a few years ago.

Reviewer 5:
This reviewer described world-class researchers and research facilities as key strengths. A weakness identified by the reviewer is the ability to turn the fundamental research into something that will impact OEM product, and added that the 2025/2030 time frame is aggressive to impact OEM product plans.

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

Reviewer 1:
The reviewer remarked that the program's projects use technically feasible, but novel and innovative, approaches to solving the problems of increasing fuel efficiency in modern day vehicles while keeping the performance acceptable and the emissions low. Just this year, two auto manufacturers announced that they are producing vehicles using technologies developed in this program, which just 5 years ago were not thought possible due to the technical barriers. This is a testament to the diligence and hard work of the DOE Program Manager.

Reviewer 2:
This reviewer indicated yes and thought this is an example of how government agencies should manage and drive technical solutions.

Reviewer 3:
The reviewer stated yes.

Reviewer 4:
This reviewer stated yes.

Reviewer 5:
Although these projects are well reasoned and logical ways to approach the issues being addressed, the reviewer was not exactly sure they represent novel approaches.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
As noted previously by this reviewer, one of the strengths of this program is the degree to which partners in academia and industry have been combined with government resources to attack the problems at hand.

Reviewer 2:
This reviewer responded positively and observed very effective engagement of industry and university partners including OEMs, Tier 1 suppliers, and other suppliers.

Reviewer 3:
The reviewer commented that the program has engaged partners in industry and academia. The program managers regularly meet with their partners to discuss progress and program goals and are well covered in this area.

Reviewer 4:
This reviewer described collaboration with LD OEMs as strong.

Reviewer 5:
The reviewer stated yes, but suggested better engagement with more universities to provide proper human resources to the industry in the future. This reviewer further commented that support to universities is relatively low-cost compared to national laboratories.

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

Reviewer 1:
The reviewer indicated yes; the combination of collaborative research programs and information sharing forums appeared to be very effective.

Reviewer 2:
This reviewer stated yes and nicely done. Further, very effective collaboration was observed by the reviewer.

Reviewer 3:
The reviewer explained that program managers have set up several avenues for industry and academia to collaborate with them. This collaboration is how they have been successful in achieving their goals.

Reviewer 4:
The reviewer commented yes and noted many interactions and collaborations among national laboratories.

Reviewer 5:
This reviewer remarked that the U.S. Council for Automotive Research (USCAR) and U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) are good approaches to maintaining awareness for both teams (DOE and industry).

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

Reviewer 1:
No major gaps were found by this reviewer.

Reviewer 2:
No significant gaps are noted, but the reviewer suggested that an emphasis on eliminating barriers towards early and fast commercialization of tools and learning should be maintained and fostered.

Reviewer 3:
This reviewer reported that in recent years, due to budget cuts beyond the program managers' control, funding to LTC techniques and LTAT has decreased.

Reviewer 4:
It was unclear to the reviewer how the "kinetically controlled" combustion mode would be achieved. Further, the reviewer commented that this mode is essentially homogeneous charge compression ignition, which has not been working out well in practical application so far.

Reviewer 5:
The reviewer asserted that addressing cycle emissions, including cold start, should be increased.

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

Reviewer 1:
This reviewer commented that all the topics have been addressed well.

Reviewer 2:
The reviewer stated no.

Reviewer 3:
There were no topics inadequately addressed observed by this reviewer.

Reviewer 4:
This reviewer suggested that greater consideration of promoting ways that combustion-based power can be merged in a more effective way in the trend towards greater electrification of power trains could be pursued, e.g., range extenders, etc.

Reviewer 5:
The reviewer stated yes and referenced prior comments.

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

Reviewer 1:
The reviewer explained that the budget seems adequate to keep the needs in hand, though no one would complain about more funding.

Reviewer 2:
This reviewer noted the cost of lean aftertreatment.

Reviewer 3:
The reviewer highlighted controls as they might aid in application of LTC combustion concepts to enhance stability over the entire operating range of the engine. This reviewer also indicated that integration of multiple alternative fuels in future engines or even more complex hybrid power trains could be potential funding opportunities.

Reviewer 4:
This reviewer remarked that more effort in LTC and LTAT are needed, and opined that this is the next area of research that will be needed to achieve DOE goals.

Reviewer 5:
Many studies on chemical kinetics were observed by this reviewer, who added that there do not seem to be as many spray studies.

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

Reviewer 1:
This reviewer observed a great approach and stated to keep up the good work.

Reviewer 2:
The reviewer indicated not at this time.

Reviewer 3:
This reviewer stated not applicable.

Reviewer 4:
As LTC becomes more prevalent, this reviewer explained that fuel properties will be more important. Subsequently, the reviewer suggested that DOE needs to engage fuel manufacturers more.

Reviewer 5:
The reviewer recommended making it easier for multiple labs to enter into collaborative research arrangements (e.g., cooperative research and development agreements [CRADAs]) with industry might help reduce barriers and promote better leveraging of the different strengths of the various national laboratories.

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

Reviewer 1:
The reviewer commented to keep going.

Reviewer 2:
The reviewer stated this is not applicable.

Reviewer 3:
This reviewer suggested to continue addressing barriers to production implementation of new ICE technologies.

Reviewer 4:
The reviewer advised to continue the trend towards building collaborative research programs and forums for combining industry, government, and university research.

Reviewer 5:
A larger budget for combustion and aftertreatment was recommended by this reviewer.

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.

Table 1-1—Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs001	Heavy-Duty Low-Temperature and Diesel Combustion & Heavy-Duty Combustion Modeling	Mark Musculus (SNL)	1-15	3.75	3.75	3.25	3.38	**3.64**
acs002	Light- and Medium-Duty Diesel Combustion	Stephen Busch (SNL)	1-20	3.25	3.13	3.63	3.00	**3.20**
acs004	Low-Temperature Gasoline Combustion (LTGC) Engine Research	John Dec (SNL)	1-24	3.30	3.50	3.40	3.20	**3.40**
acs005	Spray Combustion Cross-Cut Engine Research	Lyle Pickett (SNL)	1-30	3.75	3.67	3.75	3.58	**3.69**
acs006	Gasoline Combustion Fundamentals	Isaac Ekoto (SNL)	1-35	3.10	3.00	3.30	2.80	**3.04**
acs010	Fuel Injection and Spray Research Using X-Ray Diagnostics	Christopher Powell (ANL)	1-40	3.50	3.40	3.40	3.50	**3.44**
acs011	Advances in High-Efficiency Gasoline Compression Ignition	Steve Ciatti (ANL)	1-45	3.67	3.67	3.50	3.67	**3.65**
acs012	Model Development and Analysis of Clean & Efficient Engine Combustion	Russell Whitesides (LLNL)	1-48	3.60	3.40	3.70	3.50	**3.50**
acs013	Chemical Kinetic Models for Advanced Engine Combustion	Bill Pitz (LLNL)	1-52	3.90	3.70	3.60	3.60	**3.73**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs015	Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes	Jim Szybist (ORNL)	1-56	3.50	3.60	3.60	3.60	**3.58**
acs017	Accelerating Predictive Simulation of Internal Combustion Engines (ICEs) with High-Performance Computing (HPC)	K Dean Edwards. (ORNL)	1-60	3.50	3.33	3.58	3.25	**3.40**
acs022	Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations [CLEERS] Analysis and Coordination)	Josh Pihl (ORNL)	1-64	3.75	3.50	3.67	3.33	**3.56**
acs023	CLEERS: Aftertreatment Modeling and Analysis	Yong Wang (PNNL)	1-70	3.25	3.19	3.38	3.25	**3.23**
acs027	Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation	Abhijeet Karkamkar (PNNL)	1-77	2.93	2.43	2.71	2.42	**2.59**
acs032	Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NO_x Control & Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems	Bill Partridge (ORNL)	1-83	3.42	3.33	3.25	3.33	**3.34**
acs033	Emissions Control for Lean Gasoline Engines	Todd Toops (ORNL)	1-88	3.67	3.50	3.58	3.42	**3.54**
acs052	Neutron Imaging of Advanced Transportation Technologies	Martin Wissink (ORNL)	1-93	3.20	3.20	3.10	2.70	**3.13**
acs054	Rapid Compression Machine (RCM) Studies to Enable Gasoline-Relevant Low-Temperature Combustion	Scott Goldsborough (ANL)	1-98	3.20	3.20	3.50	3.20	**3.24**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs056	Fuel-Neutral Studies of Particulate-Matter Transport Emissions	Mark Stewart (PNNL)	1-102	3.57	3.29	3.36	3.08	**3.34**
acs075	Advancements in Fuel Spray and Combustion Modeling with High-Performance Computing (HPC) Resources	Sibendu Som (ANL)	1-107	3.50	3.50	3.67	3.33	**3.50**
acs085	Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization	Todd Toops (ORNL)	1-113	3.42	3.25	3.33	3.33	**3.31**
acs093	Lean Miller Cycle System Development for Light-Duty Vehicles	Paul Battiston (General Motors)	1-118	3.80	3.60	3.70	3.30	**3.63**
acs100	Engine Improving Transportation Efficiency through Integrated Vehicle, and Powertrain Research—SuperTruck II	Justin Yee (Daimler Trucks North America)	1-123	3.40	3.20	3.30	3.00	**3.24**
acs101	Volvo SuperTruck II: Pathway to Cost-Effective Commercialized Freight Efficiency	Pascal Amar (Volvo Trucks North America)	1-127	3.40	3.30	3.70	3.20	**3.36**
acs102	Cummins-Peterbilt SuperTruck II	Michael Ruth (Cummins-Peterbilt)	1-131	3.86	3.64	3.64	3.71	**3.71**
acs103	Development and Demonstration of a Fuel-Efficient Class 8 Tractor & Trailer SuperTruck	Russell Zukouski (Navistar)	1-136	3.14	2.86	2.79	2.57	**2.88**
acs116	Advanced Non-Tread Materials for Fuel-Efficient Tires	Lucas Dos Santos Freire (PPG Industries)	1-141	3.20	3.10	2.70	3.20	**3.09**
acs118	Advanced Emission Control for High-Efficiency Engines	Yong Wang (PNNL)	1-145	3.08	3.08	3.25	2.83	**3.07**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs119	Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NO_x and Soot Emission Reduction	Ken Rappe (PNNL)	1-151	2.93	3.07	3.00	2.79	**2.99**
acs120	Enabling Lean and Stoichiometric Gasoline Direct-Injection Engines through Mitigation of Nanoparticle Emissions	Will Northrup (U. of Minnesota)	1-157	3.43	3.36	3.14	3.36	**3.35**
acs121	A High Specific Output Gasoline Low-Temperature Combustion Engine	Hanho Yun (General Motors)	1-163	3.63	3.63	3.25	3.38	**3.55**
acs122	Solenoid Actuated Cylinder Deactivation Valvetrain for Dynamic Skip Fire	Hermes Fernandez (LLC Delphi Automotive Systems)	1-167	3.25	3.00	3.38	2.88	**3.09**
acs123	Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines	Tobias Schaedler (HRL Laboratories)	1-171	3.17	3.25	3.33	3.17	**3.23**
acs124	SuperTruck II—PACCAR	Carl Hergart (PACCAR)	1-176	3.25	2.94	3.06	3.13	**3.05**
Overall Average				**3.41**	**3.29**	**3.35**	**3.20**	**3.31**

Presentation Number: acs001 Presentation Title: Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling Principal Investigator: Mark Musculus (Sandia National Laboratories)

Presenter
Mark Musculus, Sandia National Laboratories

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 and well-planned.

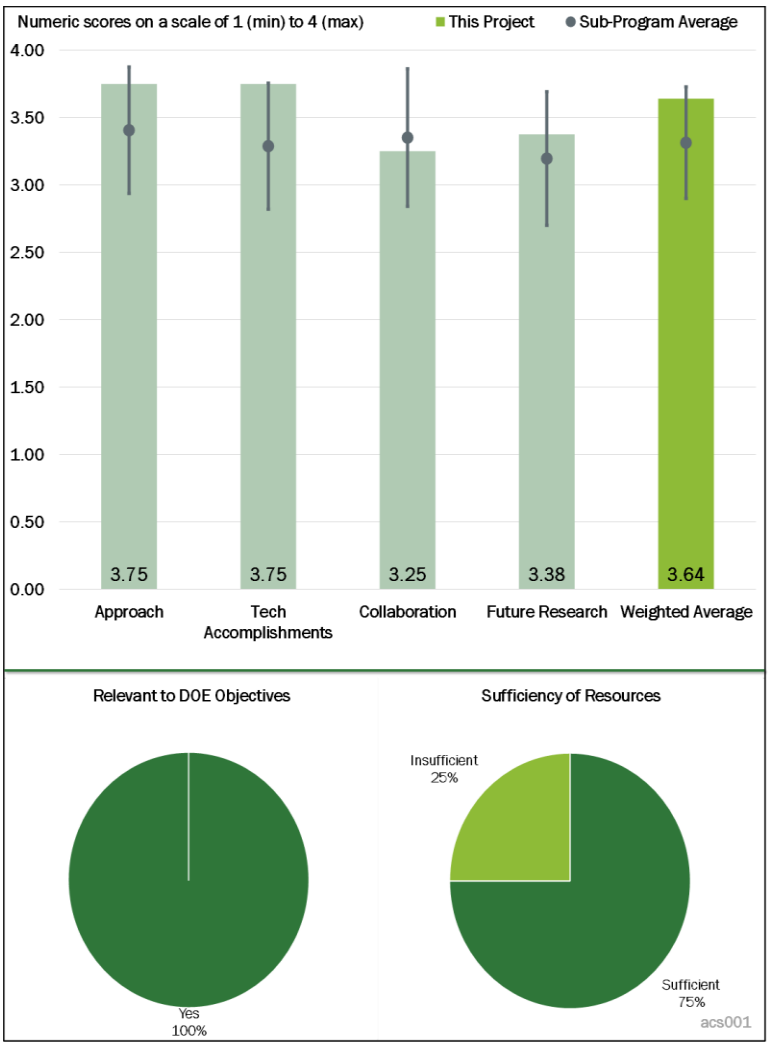

Figure 1-1 - Presentation Number: acs001 Presentation Title: Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling Principal Investigator: Mark Musculus (Sandia National Laboratories)

Reviewer 1:
The reviewer said that this project demonstrates a well-balanced approach that combines optical engine diagnostics and multi-dimensional engine simulations to understand several key problems in heavy-duty diesel (HDD) combustion system understanding and, hence, design. Examining how multiple injections interact to modify noise, emissions, and efficiency in diesel combustion is particularly important and of great practical interest to improving future production diesel engines. The reviewer commented that the fundamental work connecting polycyclic aromatic hydrocarbon (PAH) and soot distributions is also very important and exciting in its potential to impact future soot modeling capabilities. The reviewer commended the researcher and his team for conducting work that impacts understanding of both conventional mixing-controlled as well as advanced low-temperature combustion (LTC) diesel combustion strategies. The reviewer said that the program is indeed "well-designed" and has already demonstrated the feasibility of its approach to advancing understanding and addressing some of the key "technical barriers" facing diesel combustion system designers today.

Reviewer 2:
The reviewer observed very well thought-out experimental plans based on modeling and previous experiments. This reviewer observed that there seems to be careful determination of operating conditions to clarify particular areas needing improved understanding, which looks to result in relevant conditions.

Reviewer 3:
The reviewer said that the approach to this project is both experimental and computational. The thought about experimental design was clearly demonstrated with the use of sooting threshold conditions and multiple PAH

detection to address soot formation states. Additionally, the reviewer noted that the use of computational fluid dynamics (CFD) to help interrogate field quantities was/is a good approach. The reviewer said that going beyond CFD of sprays to engine-combustion CFD was discussed in the Q&A portion of the presentation.

Reviewer 4:

The reviewer said that the project team combined the laser diagnostics and numerical simulation to investigate the impacts of multiple injection on soot formation and oxidation in diesel engines, and ultimately developed a conceptual model for it. However, due to the complexity of the problem, it is very difficult to identify the influence of a single physical mechanism. The reviewer commented that it will be better to investigate the similar phenomena in a well-controlled experimental setup at first to isolate the multiple physics, and then apply to engine conditions with additional physics. Ideally, the three-dimensional (3D) combustion CFD may contribute to reveal the detailed physics behind the experimental images. The reviewer said that unfortunately, it seems that 3D combustion CFD itself has some difficulty to reproduce the process due to a lack of accurate numerical models, especially the soot model. All of these factors cast a shadow over the whole problem. The reviewer suggested that the project team may want to improve the soot model, or develop a smart way to dig into the details by using the present laser diagnostics techniques and 3D combustion CFD.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that this project has been ongoing for a long time, but with continued focus on generating science-based conceptual understanding of diesel combustion. The results presented continue to move the understanding at a good pace. The reviewer noted that publications and communication of the project results are easily found, indicating good knowledge transfer from this project to the engine combustion community. The reviewer noted that this project is one of the top DOE funded combustion projects that has direct and long-lasting relevance to the HD OEM. In-cylinder understanding of the physical processes of mixing controlled combustion systems is paramount in the HD sector. The reviewer said that mixing controlled combustion is dominant and will not be displaced by kinetically controlled combustion concepts for a multitude of technical, scientific, and economic reasons. More DOE effort needs to be pushed toward mixing controlled combustion system scientific understanding, computational modeling, and technology generation. The reviewer recommended continued strong support of this project and consider increasing its budget and scope.

Reviewer 2:

The reviewer stated that the progress of this project is great. The project team developed a combined planar PAH laser-induced fluorescence (LIF) and soot laser induced incandescence (LII) technique for in-cylinder visualization, particularly showing the interactions with the piston wall. Effects of nitrogen dilution at single injection conditions, different multiple inject strategies (close-coupled and long-dwell), and swirl have been examined in detail. The reviewer pointed out that different behaviors of PAH formation and soot under close-coupled and long-dwell have been highlighted. The 3D combustion CFD qualitatively reproduced the ignition processes of conventional and LTC diesel combustion. The reviewer said that more simulation results about PAH formation, soot formation, and oxidation are expected.

Reviewer 3:

The reviewer said that progress and accomplishments continue to be very strong for this project. The proof to this reviewer is how the research to date has already impacted how some firms design combustion systems. Some firms have utilized the PAH/soot mapping results previously presented to improve modeling soot formation in diesel simulations. The reviewer remarked that while some of the improvements are based on other sources, the research obtained from this project has played a key role in the ability to double the accuracy of soot predictions in the past 3 years. The reviewer said that significant results have already been posted and continue to be obtained towards a more fundamental understanding of multi-pulse injection/combustion dynamics and steady progress year-to-year demonstrated.

Reviewer 4:
The reviewer said that the test facility is unique, and is well-applied to the most critical areas needed research. The reviewer commented that nice progress has been made this year.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the collaboration and coordination within the team is excellent. There is a close connection between the optical engine studies done at SNL and the modeling work done at the University of Wisconsin-Madison (UW). We also see strong evidence of the collaboration and coordination with engine and injector manufacturers. From the presentation, it is not clear how the model development work is currently or will be coordinated with code vendors so that improved physical models that might be developed under this project will find their way into commercial tools used by industry, nor is the project's collaboration with Lund described in any detail. It would also be interesting to hear about any cross-coordination between the optical engine work being done under this project with the spray diagnostics work being done by other researchers at SNL or how the PAH/soot studies are impacting chemistry development at Livermore for example.

Reviewer 2:
The reviewer commented that the collaborations between SNL and UW-Madison, and between teams within SNL, are remarkable. The reviewer did not see any information about the collaborations between SNL and industrial partners. Possibly they have provided solid supports through providing hardware and software. Feedback from and/or involvement with these industrial partners may bring in some insightful ideas.

Reviewer 3:
The reviewer stated that this work is part of the MOU work, and thus has regular and effective input from industry, national laboratory, and academic partners. This is a good example of how collaboration should work. The reviewer noted that there is an upcoming SME paper ICEF2018-9733 with data that may be relevant or useful for the project team and will be presented in San Diego in November.

Reviewer 4:
Collaboration in this project seems to be mainly between SNL and the UW. The reviewer indicated that the work seems to be well-coordinated even with the limited number of collaborators.

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 although only briefly described in presentation, the proposed work appears very logical and addresses the key issues remaining in understanding multi-pulse injections and their impact on combustion and emissions. The combined experimental and analytical work promises to form a good basis for the conceptual model being developed. It is perhaps less clear how, or even if, it is the intent of the project to address the operating range limitations of LTC that prevent that strategy from making it into production HDD engines.

On a more fundamental note, one aspect of optical engine research has always troubled this reviewer is how optimized is the combustion system is that is being studied. Production diesel engines are, hopefully, based on the best (within the limits of current technology) optimized combustion systems possible. It is not clear to the reviewer what steps have been taken to ensure that the same is true for the optical engine combustion systems being studied, whether the injector, piston bowl, swirl level, etc. are well matched. SNL has developed the technique to utilize non-flat bowl shapes in optical engines, and it might be interesting to perform a

bowl/injector optimization study, perhaps in conjunction with OEM partners or even UW, to ensure that future studies are looking at how a fully optimized combustion system is behaving.

Reviewer 2:
The reviewer stated that the plan to emphasize simulations next is correct. As more simulations emerge, further experiments may be suggested. The combination of simulation and data are very strong.

Reviewer 3:
The proposed future research on the three areas listed (mixing, ignition/combustion, and emissions process) are exactly on target, according to the reviewer. These are difficult areas to work toward, however. The review presentation did not get into great detail about the physical work tasks associated with each of the three areas. The reviewer is unclear whether this may be documented somewhere else or is yet to be fully formulated. Additional insight into the proposed tasks to research on these three areas would be helpful to provide critical feedback.

Reviewer 4:
According to the reviewer, the project team has identified the current gaps in experiment and numerical simulation, and has developed a clear and feasible plan to address these issues. But there is no description about improvements in experimental and simulation techniques

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer comments that the multiple injection technique is one of the most promising technologies for improving efficiency and emission of ICEs. Understanding of its mechanism is of great importance for optimizing the internal combustion (IC) engines using this technique. It is also a challenging condition for the modern soot models. This work intends to reveal the fundamental mechanism of the multiple injection effects on mixing and soot formation/oxidation by developing a conceptual model. The work may lead to improvements in spray models and/or soot models for 3D combustion CFD. The outcomes of the present project will benefit the engine industry by improving the physical understanding and potentially improving 3D combustion CFD models.

Reviewer 2:
The reviewer commented that this project is very relevant to improving diesel engine combustion, improvement of efficiency, and reduction of emissions. The information developed here will help engine designers directly, and by improving simulation ability, will provide tools for engine designers and developers.

Reviewer 3:
According to the reviewer, yes, this project supports the overall DOE objectives. Enhanced scientific understanding of diesel and mixing-controlled combustion processes clearly allows better optimization of combustion systems for increased efficiencies (reduced energy consumption) at the same or reduced emissions levels. Knowledge gained in this project is additionally vetted against CFD tools, which can enable a direct transfer to industry via these simulation tools.

Reviewer 4:
According to the reviewer, the research supports the DOE’s objectives of driving up efficiency while driving down emissions.

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

Reviewer 1:
The resources seem appropriate given the shift toward simulation. However, if future developments require more experimental work, there may be a need to restore some of the past funding levels.

Reviewer 2:
The reviewer commented that the team has the access to the world top facilities of laser diagnostic and optical engine. The team consists of top experts in laser diagnostic, diesel engine, and 3D combustion CFD and is rich with experience.

Reviewer 3:
Because the SNL experiments are in an optical engine with a multi-hole combustion system, the CFD side of the project should quickly be following suit to achieve the project milestones in a timely manner. Presently, the CFD work focuses on single-spray simulations. The reviewer suggested adding scope/resources or quickly moving toward engine-combustion CFD simulations to really extract understanding and play on the different strengths/weaknesses of the experimental and CFD methods. Gaining access to HPC resources may be an easy way to accelerate the computational side of the project without adding substantial cost.

Reviewer 4:
Per the reviewer, resources being utilized for this project are sufficient to achieve the stated milestones in a timely fashion.

Presentation Number: acs002
Presentation Title: Light- and Medium-Duty Diesel Combustion
Principal Investigator: Stephen Busch (Sandia National Laboratories)

Presenter
Stephen Busch, Sandia National Laboratories

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 and well-planned.

Reviewer 1:
This project seemed to have well-coordinated experimental and modeling. The reviewer stated that with more funding, it would be of interest to investigate the fundamentals behind other geometrical changes than just conventional versus stepped lip piston, such as various squish clearances and other features.

Reviewer 2:
The reviewer considered the approach to this work is quite good, and considering the redirection and course change, well communicated and documented. Combining optical engine experiments, CFD, and metal engine experiments demonstrates the use of almost all the combustion tools available for project execution. However, because the project has been recently redirected, future clarification of critical tasks is expected.

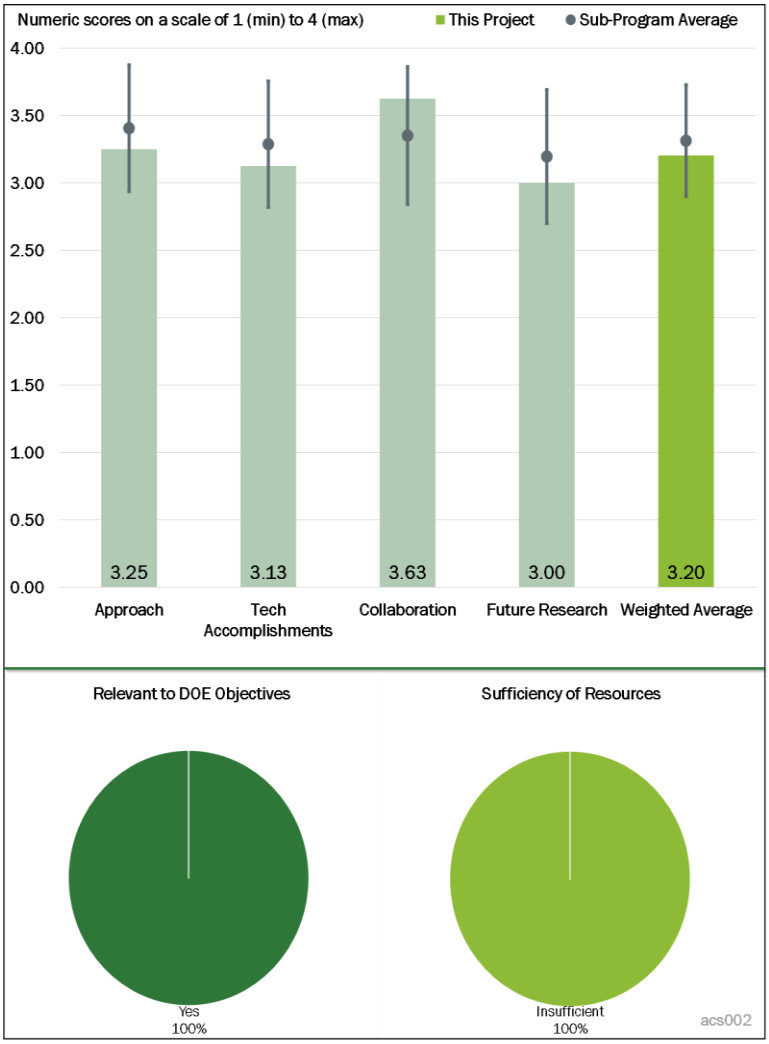

Figure 1-2 - Presentation Number: acs002 Presentation Title: Light- and Medium-Duty Diesel Combustion Principal Investigator: Stephen Busch (Sandia National Laboratories)

Reviewer 3:
Past experimental work on flow visualization in the bowl rim area, and the associated CFD focuses on better understanding the influence of piston design on flowfield behavior, appears to be valuable toward one project objective of developing an engineering conceptual model for relating spray targeting to emissions formation in-cylinder. One question that arises though is the influence of piston speed and load on these local flowfield structures. Per the reviewer, more work could be done to address that shortcoming in the future.

Regarding the second part of this project, targeting better understanding of catalyst light-off, it is not clear what type of conceptual model is in the works for engineering purposes. The reviewer stated that this project has experienced recent redirection and thus it may be too soon to have the conversation about the conceptual model development.

Reviewer 4:
The reviewer commented that the technical barrier was well pointed out, although the reviewer is not sure what level of understanding of physics and model verifications are pursued. Ideally, a full optical engine running at conventional conditions will be needed, which is challenging technically. It is not very clear if the work is to address such problems.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that the combustion image velocimetry proved to be very insightful and that there was a good description of recirculating flow structures effects.

Reviewer 2:
The reviewer considered the progress on this project strong, especially considering the flux and redirection. The piston bowl portion of the project is a good example of fundamental combustion system physical understanding. The ability to identify flow fields and relate them to mixing, heat release, and emissions is demonstrated clearly. Engine OEMs develop combustion systems and regularly understand the net effects, but have lower levels of access to in-cylinder experimental understanding. The movement of the project towards using CFD is a good step towards enabling verification of this project's experimental results. Spray-wall interactions are critical in mixing-controlled combustion system design and this reviewer recommends the experimental work start again once the move to the 100 meter bore platform has been made. There is a wide body of knowledge on spray-wall combustion system design, so the reviewer suggested the project reach out to industry for continued engagement for enhanced understanding and alignment. Preliminary data for cold-start operation shows a quick transition to the second aspect of the project and its redirection.

The reviewer pointed out that mixing controlled combustion is dominant and will not be displaced by kinetically controlled combustion concepts for a multitude of technical, scientific, and economic reasons. The reviewer said that more DOE effort needs to be pushed toward mixing controlled combustion system scientific understanding, computational modeling, and technology generation. The reviewer recommended continued strong support of this project and to consider increasing the budget and scope.

Reviewer 3:
This project was redirected twice and the reviewer suspected that such changes impacted the technical accomplishments during the last year. A new thrust of cold-start light-off was added to the project, and like any new thrust, slowed down progress. The project team and collaborators spent a significant amount of time analyzing optical engine data and employing CFD to help better understand some of their experimental observations. It would have been beneficial if additional optical engine data were available for various engine speeds and load conditions to augment the learning process. But again, the project was redirected twice and that may have limited the capability of the project team to execute additional experimental work.

Reviewer 4:
The reviewer commented that the overall accomplishments and progress look weak, although it seems that funding was a limiting factor.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the project coordination seems to be quite good. Coordination difficulty often increases as collaborator number increases, and there are six collaborating parties in this project. The roles of each party were clear and documented.

Reviewer 2:
The reviewer stated that the collaborations look good, overall. Having information available on the Engine Combustion Network (ECN) database is a good choice, so that others (outside the industry partners) can try the same practice. A line mentioning about CD-adapco was a little hard to understand. It is always a good idea to have multiple tools trying the same problem. The reviewer inquired if CD-adapco is reluctant to collaborate. There should not be any technical problem in processing engine geometry files to convert to mesh.

Reviewer 3:
According to the reviewer, this project was a clear collaboration and coordination with two LD companies, a HD company, and two software application companies. This team appears to be working well together in analyzing and extracting whatever understanding is possible from the experimental optic engine data.

Reviewer 4:
To this reviewer, it appeared to be a wide collaboration. The reviewer questioned what aspects can be accelerated, specifically on the Wisconsin Engine Research Consultants sub-contract.

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 proposed future work plan seems to be good. Due to the project redirection, there is some uncertainty and likely a lower level of work that will be completed in fiscal year (FY) 2018, purely due to the prior project uncertainty. The reviewer is concerned about the plans to get the new 100 millimeter bore metal and optical engines up and going. This may take significant effort and time and reduce the ability to conduct the catalyst heating experimental activities. The reviewer recommended watching for this potential resource conflict.

Reviewer 2:
The reviewer said that it would be great to see more experimental work at varying engine speeds and loads, and also see a game plan for developing conceptual models for both the spray-wall interaction thrust and also the cold start light off thrust. The reviewer understood that the second thrust is a new one, but if the goal is truly to develop engineering level conceptual models, then possibly more attention to scaling key measurements/parameters to engineering understanding is worthwhile.

Reviewer 3:
The reviewer stated that including an aspect of high swirl versus moderate swirl could be useful for further insight.

Reviewer 4:
According to the reviewer, the plan makes sense only with the new optical engine waiting for funding approvals.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said yes, this project absolutely addresses DOE objectives. Each part focuses on enabling higher efficiency, low emission IC engine technology development though each part has a different focus. Studying the cold-start catalyst light-off from a scientific viewpoint with the hope of lighting off sooner by using the minimum amount of fuel will be a challenge, but nevertheless could be helpful toward the objective of engineering conceptual model with the hope of aiding the further development of advanced gasoline engine technology possibly including lean burn operation.

Reviewer 2:
The reviewer remarked yes, this project supports the overall objectives of the DOE. Per the reviewer, enhanced scientific understanding of diesel and mixing-controlled combustion processes clearly allows better optimization of combustion systems for increased efficiencies (reduced energy consumption) at the same or reduced emissions levels. The knowledge gained in this project is additionally vetted against CFD tools, which can enable a direct transfer to industry via these simulation tools.

Reviewer 3:
The reviewer stated that this project is fundamental to efficiency and emissions optimization for multiple paths of IC engines in future.

Reviewer 4:
The reviewer commented that, yes, the project supports DOE objectives to reduce engine emissions and improve fuel economy.

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 this project budget seems a little low considering all of the project work effort by the various partners. But, the project team did comment that their national laboratory received approval to bring on-line a modern multi-cylinder engine via DOE funding. So, the reviewer is unsure if the budget truly is insufficient or not. The presentation generally pointed toward a lack of funding.

Reviewer 2:
According to the reviewer, this project should be in line with 2017 budget, which was $800,000-$950,000 per year.

Reviewer 3:
The reviewer commented that a new optical engine is a critical piece for the success of the project.

Reviewer 4:
The reviewer has indicated that the resources for this project are insufficient due to the new 100 millimeter bore platforms. This is a substantial effort and if significant money and labor are not allocated to this, the present funding of $200,000 will not work. The reviewer assumed that once the 100 millimeter bore approval is gained, then the resources and funding will be appropriately matched.

Presentation Number: acs004
Presentation Title: Low-Temperature Gasoline Combustion (LTGC) Engine Research
Principal Investigator: John Dec (Sandia National Laboratories)

Presenter
John Dec, Sandia National Laboratories

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 and well-planned.

Reviewer 1:
The reviewer said that LTC has been a concept promising very good efficiencies with very low emissions for decades, but has been plagued by the inability to control combustion timing, particularly at high loads. Gasoline, while widely used for SI engines, has potential benefits to compression ignition (CI) engines as well in terms of emissions and potential future costs as the transportation landscape continues to change. This project does an excellent job of exploring the concepts of LTGC through a wide range of studies involving metal and optical engines and, increasingly, multi-dimensional engine simulation. Of particular note is the progress made in controlling combustion timing through developing an apparently successful, although yet to be fully explored, technique based on introducing controlled amounts of an ignition enhancing additive during each engine cycle as required. Overall, the approach taken is very effective in addressing the many technical barriers to using LTGC via very systematic research utilizing resources of government national laboratories, universities, and industry, and makes a compelling story that might just demonstrate the practicality of this technology for future production IC engines.

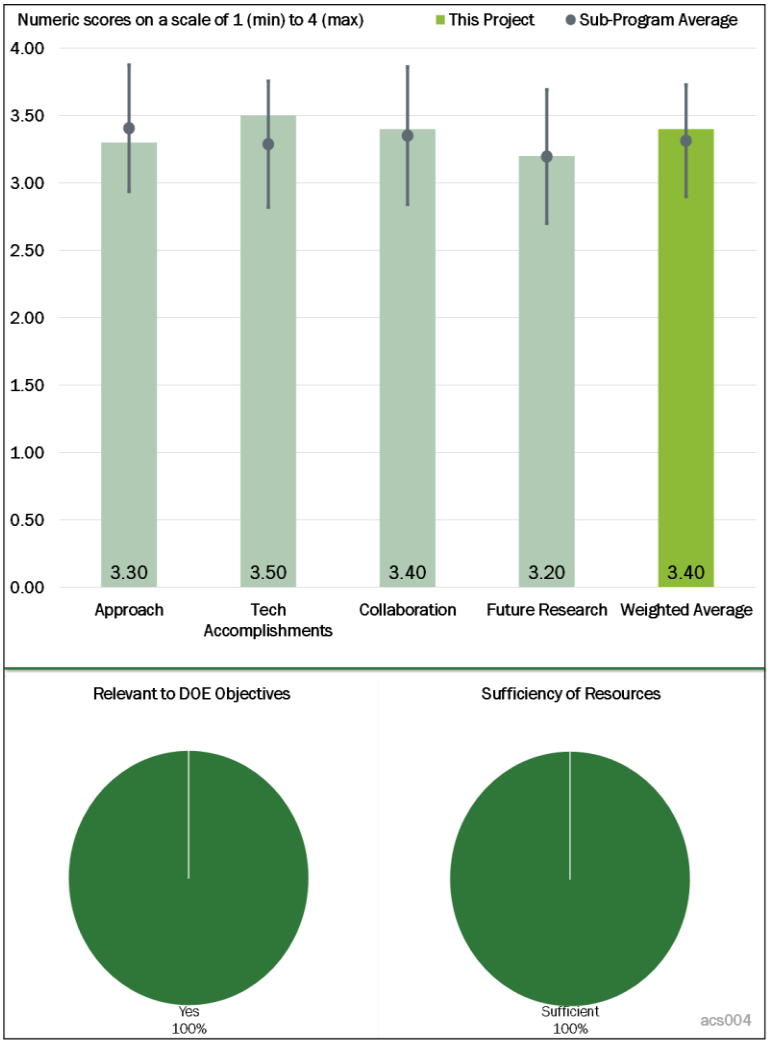

Figure 1-3 - Presentation Number: acs004 Presentation Title: Low-Temperature Gasoline Combustion (LTGC) Engine Research Principal Investigator: John Dec (Sandia National Laboratories)

Reviewer 2:
The reviewer commented that the approach is generally very good. It seems that sufficient data have been taken and that optical measurements are in order. As an example, the CFD work from State University of New York at Stony Brook (Stony Brook) should be compared to the current engine, and not data from 2012, which the reviewer presumed is a different engine. The presentation included a slide on phi sensitivity (Slide 30) that was not in the material given to the reviewers. When the author presented the slide, it was accompanied by a comment that "This slide is complicated and I do not have time to explain it," which was not helpful to this reviewer.

Reviewer 3:
Per the reviewer, this project is very well developed. It brings together a range of collaborators with wide-ranging expertise to address the problem of understanding the practicality of low-temperature gasoline combustion (LTGC) technologies. In the experiments, the PI uses an optical and metal single cylinder engine to develop a better understanding of LTGC and to leverage the capabilities of the collaborators that will ultimately facilitate transfer of the results to industry. The SNL LTGC laboratory is a world leader in engine testing; the great benefit is derived from results reported to achieve the desired understanding that can make viable LTGC a reality. The reviewer pointed out that CFD modeling is included, and new combustion timing control techniques are investigated. Using 88-octane research gasoline (RD587) fuel is particularly appropriate to reduce uncertainty in 10% ethanol content gasoline (E10) compositions that can often arise.

The approach of using the project team's single cylinder engine designs is quite appropriate and very useful. The reviewer stated that it would perhaps be good to highlight how results from single-cylinder engine tests would provide the type of data that the OEMs will find useful in engine design. It would also perhaps be useful for the project team to articulate the link to multi-cylinder configurations that the OEMs would find most useful. Although this has been done in past work, it would not hurt to mention the link. The reviewer considered the comparisons between the surrogates and the model fuel investigated in the experiments very appropriate and significant.

The reviewer noted that the presentation noted a new collaboration on CFD with a university partner, and recommended presenting more on this, because national laboratories are developing robust capabilities for modeling in-cylinder processes, and the PI noted collaborations with ANL to compare his engine data with ANL predictions. The reviewer stated that this is good and that more should be presented on this. The reviewer questioned what the added university capabilities bring to the project that the ANL collaborations do not. Presumably, with ANL, CONVERGE is being used.

Regarding collaborations with LLNL on kinetic models, the reviewer stated that more should be provided on precisely how the engine results can inform development of kinetic models. Certainly, the engine data are appropriate and novel. However, precisely how they will fold into development of kinetic models is not clear.

Reviewer 4:
The reviewer said the idea of using a second additive fluid to control crank angle position at which 50% of heat is released (CA50) is a good one. However, before too many resources (time, money) are spent on developing and researching this idea, quick experiments should be conducted to evaluate both the technical benefits and the commercial viability of such a concept. CA50 needs to change in the order of 2-3 engine cycles (100 -300 milliseconds). Having a LD customer fill a second fluid at oil-change intervals is an idea that has been met with very high resistance.

Reviewer 5:
The reviewer remarked that using large eddy simulation (LES) CFD model can offer insight to engine behaviors, but asked how it is relevant to simulate one geometry and compare it to a different geometry in the engine. The reviewer commented that the new approach of using an ignition additive may finally address the combustion phasing problem.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that accomplishments and progress in this program are quite remarkable, especially in the context of the amount of effort that has been expended over the years by other researchers to achieve the level of control needed to make LTC practical over the entire operating range needed for production engines. Adding CFD studies to understand turbulent mixing effects on stratification is particularly noteworthy, as are plans for optical engine studies; both should accelerate future progress of this project.

Reviewer 2:
The surrogate kinetic work is very good and important. The reviewer questioned what the additional computational overhead time that results when it is used. It seemed to the reviewer that with the variation of the mixing from cycle to cycle, as well as the variation of thermal stratification, phi sensitivity variation between fuels is something to minimize. Others have suggested using ethylhexyl nitrate (EHN) as an ignition improver. To this reviewer, it seemed that the potential use of additive-mixing fuel injection (AMFI) will supersede or minimize other concerns, like phi sensitivity.

Reviewer 3:
The reviewer stated that very good progress has been made, as follows: When applying LES to understand sources of thermal stratification, the reviewer questioned the role or potential of intake generated turbulence on the transient control of CA50, if thermal stratification, needed for control of CA50, is caused by intake generated turbulence. An improved surrogate for regular E10 fuel has been developed. Both this model and the LLNL model seem to work well. The reviewer said the relationship of phi sensitivity to octane sensitivity has been investigated and an electrolyte primer blend "Blend 3" has high phi sensitivity as well as high research octane number and high sulfur (S). A new concept has been developed for rapid control of CA50. According to the reviewer, the issue will be a transient response related to the additive delivery system, mixing of additive and fuel, and dead volume. These parameters should be quickly designed to make sure they can be easily engineered.

Reviewer 4:
The reviewer commented that the project has established a collaboration with a modeling group to assist in the explanation of the results. This is good. CONVERGE CFD software is being used. Because ANL is investing heavily in CONVERGE CFD for engine simulations, the reviewer questioned whether there are any collaborations with ANL. The reviewer noted some information on CFD "validation." Because the in-cylinder environment is so complicated, precisely how validation can be accomplished with this engine configuration is unclear. If sub-models are needed in CONVERGE CFD, their uncertainties can be a factor in validation. The reviewer questioned whether there are any multiphase (e.g., spray/gas interactions) that is expected and included in the simulation.

The reviewer pointed out that the experimental comparisons between research gasoline for performance comparison (RD587) and the various surrogate blends is excellent. They show the value of the surrogates developed. Interestingly, the binary performs almost as good as the four-component system. This result provides a significant advantage in modeling (a two-component blend is far easier to deal with than a four-component blend). The reviewer noted that software for the conceptual development of combustion systems (CHEMKIN) simulations is being pursued. The reviewer questioned whether this is for the engine or, say, a homogeneous reactor or other combustion configuration with a low-dimensional transport.

Reviewer 5:
The reviewer stated that development of a unique fuel formulation to enable a certain combustion approach will not be commercially relevant. The combustion approach must be compatible with the full range of available retail market gasolines in order for a manufacturer to embrace it. Using the ignition additive is a good step, but the team must show it to be effective regardless of the fuel. The transient torque response requirements for LD applications are on the order of a hundred milliseconds, so an order of magnitude improvement in transient response is required. The ignition additive delivery system would have to be developed to reflect this requirement. The reviewer said that a claim of low particulates was made, but no results were shown that demonstrate this.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the kinetics work of LLNL and the CFD work at Stony Brook are strong contributions to this program.

Reviewer 2:
The reviewer commented that the collaborative team is very good, as it includes a combination of extensive engine experiments and collaborations with those doing CFD modeling. CFD modeling is almost a necessary/required component to make sense of the experimental results, and the project team has an excellent group of collaborators. The reviewer said it would be useful, perhaps, to say more about collaborations with national laboratories doing similar collaborations. The author mentioned ANL, for example. Of particular interest is precisely how the CFD modelers use the engine data and how the engine data inform development of surrogates.

Reviewer 3:
The reviewer said that collaboration has been very good in the past and is getting stronger with addition of Stony Brook for CONVERGE CFD studies. The reviewer stated that while some explanation of how LLNL kinetics, etc. research is being integrated into this project, the role of ANL's rapid compression machines (RCM) work is less understood and could be more clearly described. While OEM interaction on the smaller engine side is clear, there does not seem to be much interaction on the HD end of the spectrum and could be increased as this technology would definitely be of interest there as well.

Reviewer 4:
Per the reviewer, collaborations are adequate. Additionally, it is good to see the addition of a CFD partner to support the work.

Reviewer 5:
The reviewer stated that collaborations exist with General Motors Corporation (GM).

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 project team has identified a number of aspects that need additional work: cycle-to-cycle variations for higher fuel rates; how intake flows produce large scale turbulence and robust ignition; infrared (IR) imaging of fuel distribution; and closed loop feedback control system. The CFD modeling that notes "fuel sprays..." perhaps deserves further elaboration. Incorporating fuel sprays in engine simulations is an extremely difficult problem. A lot of groups have been working on this but without full success yet. The reviewer pointed out a question to close the gap between modeling and engine experiments is what do the modelers need that excellent engine testing here provides.

Reviewer 2:
The reviewer found that the proposed research moving forward is clearly presented and focuses on furthering understanding the AMFI control system, the role of multiple injections on combustion timing control, further CFD and optical studies on fuel stratification, and devising better mechanisms for CA50 control. All of these are vital areas of research to further the development of LTGC.

Reviewer 3:
Continued investigation into the use of the ignition additive is important to determine if this is a valid approach. The reviewer commented that an improved control system will contribute to this by investigating the transient torque response to be sure that it is fast enough.

Reviewer 4:
The reviewer said that some effort has to be expended to show potential for commercialization of the LTGC concept with the ignition enhancing fluid.

Reviewer 5:
The reviewer is puzzled with some of the future directions of this project. The reviewer understands that the objective of the research directed towards LD is for multi-mode combustion: kinetically controlled combustion at lighter loads, which is transitioned to active ignition at high loads. The reviewer questioned whether or not the transition between kinetically controlled and active ignition should be a focus of study. Also, as long as the project team is going to have an active ignition system, the reviewer questioned the use of the EHN system versus using that for CA50 control. Given that the project team will not pursue max load through kinetically controlled combustion for light load operation, the reviewer questioned why this is being pursued for medium-duty/HD operation.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said yes, from a broad perspective, this project will support the overall DOE objectives. The project focuses on LTC from the perspective of gasoline fueling engines under diesel-like conditions. The project is also relevant to multimode operation that can improve efficiencies of diesel engines. Aftertreatment costs are also expected to be reduced. The reviewer found all of this to be very nice.

Reviewer 2:
The reviewer commented that this program endeavors to advance efficiency and emissions goals of DOE and may also impact DOE alternative fuel scenarios as well.

Reviewer 3:
The reviewer found that potential performance gains and overall system greenhouse gas reductions through advanced combustion system with environmentally optimized fuels will be an important component of moving toward sustainable mobility.

Reviewer 4:
The reviewer said that questions remain regarding robustness to variation in market fuels, ambient environmental conditions, and transient response. The reviewer commented that this work will be relevant only when all of the barriers to implementation are addressed.

Reviewer 5:
According to the reviewer, engine efficiency can be improved significantly if this project is successful.

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

Reviewer 1:
It appears to the reviewer that resources are sufficient to achieve stated milestones and objectives.

Reviewer 2:
The reviewer stated that resources seem sufficient and the project team has had success with initiative to get additional support when needed.

Reviewer 3:
Per the reviewer, the funding is adequate and should not be increased.

Reviewer 4:
The reviewer commented that the stated milestones can be achieved.

Reviewer 5:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Presentation Number: acs005
Presentation Title: Spray Combustion Cross-Cut Engine Research
Principal Investigator: Lyle Pickett (Sandia National Laboratories)

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 and well-planned.

Reviewer 1:
The reviewer found the approach to this work is excellent as exemplified by the success of the ECN. Clear experimentation and simulation techniques have been brought together to advance the project goal of allowing the development of predictive computational tools for industry.

Reviewer 2:
The reviewer's opinion is that this is a great program. It is a coordinated effort to advance our understanding and improve our simulation accuracies and fidelity along with experimental accuracies and protocols through the international collaboration of all interested stakeholders. This project appears to be working well.

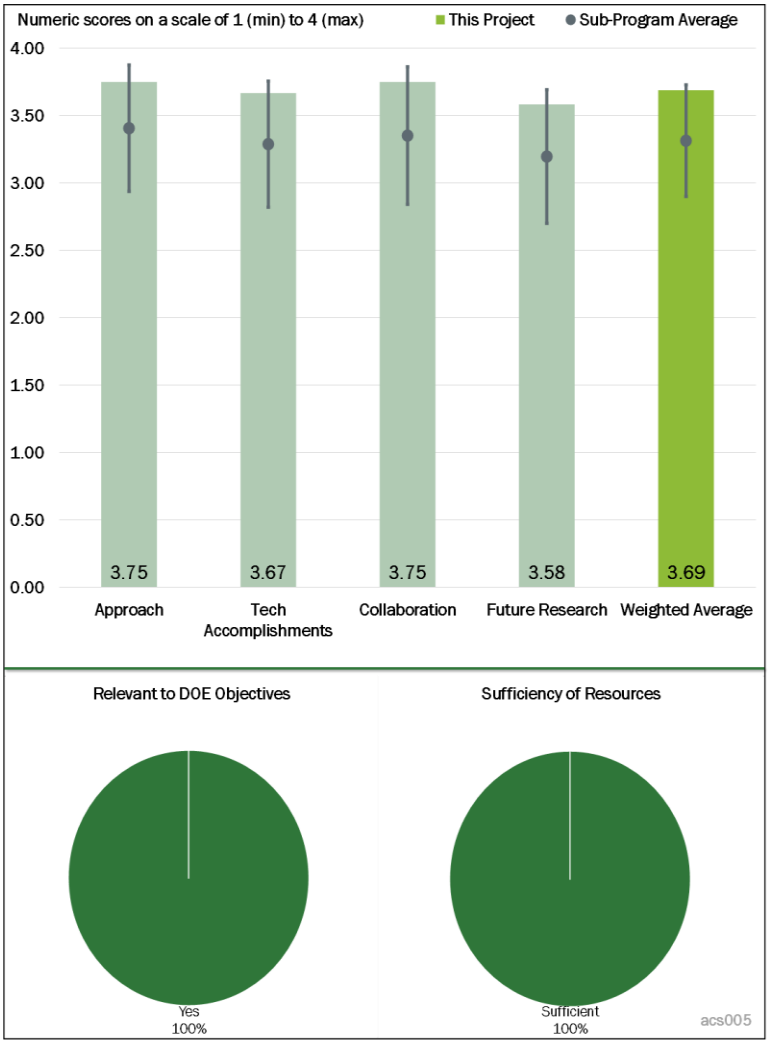

Figure 1-4 - Presentation Number: acs005 Presentation Title: Spray Combustion Cross-Cut Engine Research Principal Investigator: Lyle Pickett (Sandia National Laboratories)

Reviewer 3:
The reviewer commented the project team has developed and applied different diagnostics techniques to characterize the spray and flame. Some techniques have shown great success, or potential, in revealing the fundamental mechanisms of the spray combustion. For the unsuccessful ones, the project team has honestly addressed the limitation and disadvantages, which is also a good contribution to the community. For soot formation in GDI engine-like condition, the spray injection event makes the process much more complicated. The reviewer said that the project team may consider use a pool of liquid fuel to mimic the wall film, which will ease both measurement and simulation. The project may highlight some successful stories about comparison between experiments and simulations, and/or the impacts of the present project on model developments and validations.

Reviewer 4:
The reviewer found the project to be well-designed and well-planned.

Reviewer 5:
Using advanced spray diagnostics in a high-pressure, fixed-volume vessel allows detailed information to be gathered on gasoline, diesel, etc. fuels in an environment much less complex than an engine cylinder with a moving piston, complex charge motion, etc. The reviewer comments that this allows many technical barriers to higher-efficiency, lower-emission IC engines to be carefully studied and provides much useful data for spray and combustion model development, calibration, and validation for multi-dimensional engine simulation tools that industry needs to design future combustion systems and injectors.

Reviewer 6:
The plot box on the top right side of Slide 10 is singularly dark blue and the reviewer questioned whether this is accurate. The reviewer was unclear which fuel was used for the results shown on Slides 9, 10, 16, 17, 19, and 20.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Significant accomplishments in many areas continue to be made that offer significant progress to achieving overall project goals of more efficient and, in particular, cleaner engines. The reviewer commented that it would perhaps be useful to incorporate some parallel CFD-based research to assist in interpreting and rounding out the information gathered in the experimental work, similar to the approach now being used in the optical engine research at the same laboratory.

Reviewer 2:
The reviewer believed this project is very productive. For measuring techniques, the project team has developed high-speed imaging extinction diagnostic for quantitative measurement of spray mixture and multiple wavelength extinction measurements for soot refractive index study. The project team has applied particle image velocimetry to GDI multi-injection spray, and soot extinction imaging to soot emission near wall film. The team has investigated several engineering problems, including spray and combustion behavior of fuel for engine testing (AVL-18a) diesel surrogates, soot formation near GDI injector, mixing in transient spray, soot formation in pyrolyzing spray, and multiple injection.

Reviewer 3:
The reviewer remarked the technical accomplishments of this program in FY 2018 look to be moving very well. The new mixture quantification absorption diagnostic looks very interesting and may be a key output for other institutions to enact. The work on wall films and sooting looks to be going well also. The reviewer found the presentation to be a bit unclear about the pyrolysis experiments and how to interpret their meaning with respect to the wall films. The reviewer expressed certainty that more time would allow sufficient detailed understanding. This project has been invaluable over the years to OEMs needing to understand and leverage spray diagnostic capabilities. The reviewer also encouraged continued strong support of this project and to consider increasing budget and scope.

Reviewer 4:
The reviewer stated that the results are very insightful as to what fundamental understandings are inadequate and need enhancement before higher fidelity simulations can be developed.

Reviewer 5:
The reviewer said that the team carefully performed a series of tests to evaluate various laser diagnostics techniques and obtained useful guidelines. The reviewer commented, however, the conclusions on the difficulty of the Rayleigh scattering were previously reported in literature. For the quantitative mixing measurement, fullerene molecule used as a conductor (C70) seems to be a promising dopant, but the team needs a careful comparison for distillation matching.

Reviewer 6:
The reviewer found Slide 22 to be clearly stated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer could only describe collaboration from this project as outstanding. The reviewer stated that the ECN has proven to be a great success due to this project and the collaborative leadership. Furthermore, continued collaboration with industry is highly valuable as well.

Reviewer 2:
The reviewer indicated that one of the outstanding success stories of the entire DOE VTO is the ECN created and managed through this project, particularly in the area of GDI experimental and analytical research collaboration. The reviewer noted, of course, it would be beneficial to the diesel OEMs to see more work done on the diesel side. Additionally, the reviewer noted that there are certainly plenty of problems to consider, particularly in the area of spray/soot relationships. In this context, a greater collaboration with the same national laboratory's optical engine program might generate even more interesting results.

Reviewer 3:
The reviewer found this to be a great collaborative effort.

Reviewer 4:
The reviewer commented that ECN covers the majority of research groups in characterization and simulation of spray combustion in this world. Efficient collaborations have been achieved through the ECN monthly meeting, whose attendees include not only the ECN research groups but also engineers from industry. Per the reviewer, the groups honestly compare their measured and simulated results. The published ECN data have been extensively used to validate spray and combustion models. Such crowdsourcing collaborations have significantly advanced the progress of spray combustion research. The ECN has set up a very successful model for international research collaboration.

Reviewer 5:
The reviewer noted that the ECN has very good collaborations. The ECN partners participate and are well-coordinated.

Reviewer 6:
The reviewer recommended clarifying who does what during collaboration.

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 new "high-throughput" facility will be exciting, particularly if it lives up to its name by allowing more data to be gathered even more quickly. The overall future research plan proposed is excellent but of course, more is always better, so hopefully future reports will show even more results in more areas. To reiterate a previous comment, particularly in the area of diesel research.

Reviewer 2:
The reviewer remarked that Slide 21 is clearly written.

Reviewer 3:
To the reviewer, the team has identified the most-appropriate challenges to pursue in the ongoing work. The reviewer agreed with the focus of the project's future work.

Reviewer 4:
The reviewer said that the project team has identified soot emission and flash boiling as the major topics for gasoline engines, internal flow, droplet behavior under supercritical conditions, mixing, and ignition for diesel engines. The reviewer considered all of these topics of great importance for industry. For soot emission in gasoline engine, the research plan needs improvements. The current configuration does mimic the engine conditions, but it becomes quite complicated due to the injected spray and consequent wall impingement events. The reviewer said that a simpler and better controlled configuration is required to isolate part of the factors influencing the whole process.

Reviewer 5:
The reviewer remarked the future FY 2019 work seems to be in a very good position. The reviewer recommended considering engagement with the ECN community and OEMs for specific guidance. The reviewer did not see any discussion of decision points, which may be helpful along the way. Specifically, as the new vessel is brought online, there may be opportunities to leverage the new capability to best accelerate or increase the scope.

Reviewer 6:
The reviewer commented that the plan seems effective.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said this project greatly supports the DOE objectives. Great advances in engine combustion understanding and predictive capability have come about from this project and the ECN. This is one of the top DOE funded experimental combustion-spray projects.

Reviewer 2:
The reviewer commented that certainly the research conducted under this program has had, and promises to continue to have, a major impact on reducing emissions from future IC engines. The direct connection between spray research and engine efficiency is a little harder to gauge, so more work perhaps is needed to envision experiments that might highlight this connection better.

Reviewer 3:
The reviewer said that this project improves the understanding of soot formation and the wall impingement.

Reviewer 4:
Per the reviewer, spray characters significantly influence combustion performance of both SI and direct-injection (DI) engines including efficiency, emissions, engine knock, and combustion stability. The whole industry suffers from lack of predictive CFD tools. The present project characterizes the spray and resulting flame under engine-like conditions using advanced measuring techniques, which generates high-fidelity data for model validation. The reviewer said that the project aims to provide fundamental understanding of the relevant physical processes in modern diesel and gasoline engines. The outcomes of the project also have the potential to be applied to other liquid fueled combustion system.

Reviewer 5:
The reviewer believed that this project fits in the DOE goal.

Reviewer 6:
The reviewer referenced prior comments.

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 team has access to the world's top facilities to characterize the spray and flame. The ECN groups include top research groups in measuring and simulating spray combustion. With this good relationship with industry, the team has access to injectors from leading manufacturers including Bosch and Delphi.

Reviewer 2:
The reviewer stated that the resources appear to be adequate for the proposed research.

Reviewer 3:
The reviewer commented that the project team has sufficient recourse.

Reviewer 4:
The reviewer remarked that it seems that the funding level is adequate.

Reviewer 5:
The reviewer stated that it looks okay but the reviewer does not feel to be in an adequate position to judge this.

Reviewer 6:
The reviewer indicated that the project seems to have sufficient resources. However, the reviewer has concern with the new high output vessel coming online in FY 2019. If this funding is coming from Co-Optima, then this may be okay, but the personnel aspect may still be of concern.

Presentation Number: acs006
Presentation Title: Gasoline Combustion Fundamentals
Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

Presenter
Isaac Ekoto, Sandia National Laboratories

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 and well-planned.

Reviewer 1:
The reviewer found that the fundamental measurements and studies to understand the impact of ozone generation on ignition processes to be very good. This can have wide application to in-cylinder processes as well as, potentially, for aftertreatment in certain operating modes. The reviewer believed that this area of study should be extended to evaluate the impact of ozone generation on conventional SI conditions, conventional CI conditions, and to ozone generation from more conventional ignition systems where the ozone yield is smaller but still of interest. For the reviewer, the effort to investigate transient plasma ignition (TPI) in the engine is also of interest. The reviewer would like to see analysis/discussion of the suitability of the test engine to the system as there has been some evidence in the past that high compression ratio small bore engines can be challenging for generation of the plasma rather than arcing due to the small path length available between metal surfaces.

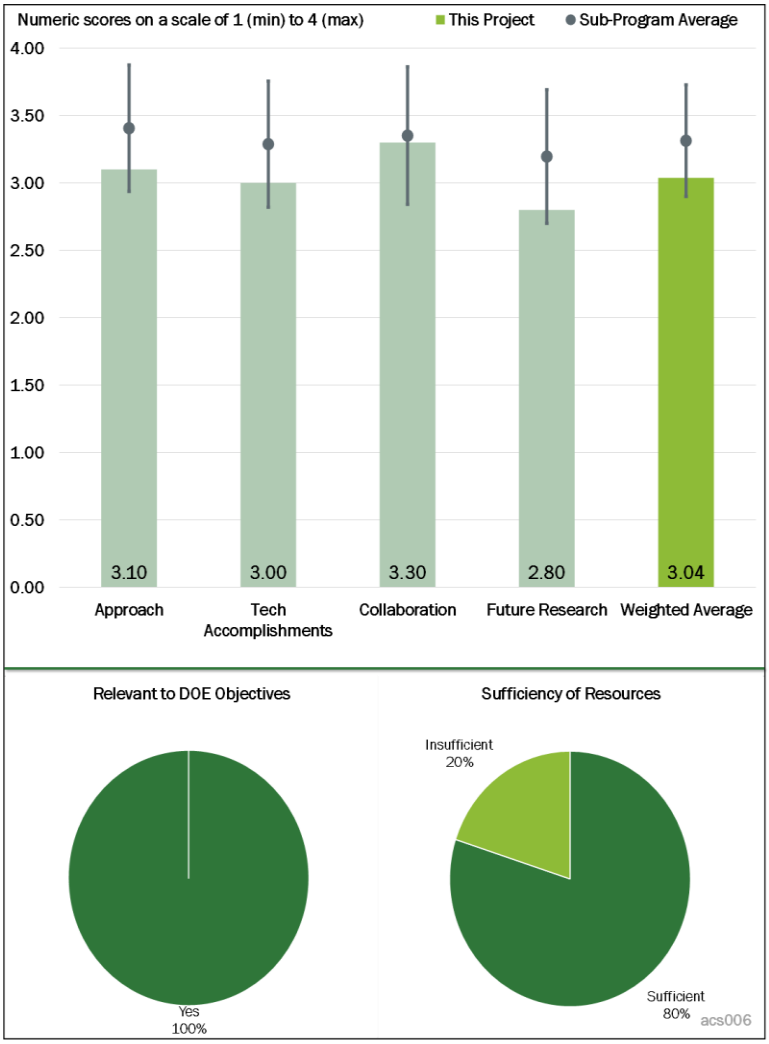

Figure 1-5 - Presentation Number: acs006 Presentation Title: Gasoline Combustion Fundamentals Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

The reviewer has concerns with the current approach for the turbulent jet ignition (TJI) studies. While it is admirable to simplify the system to something that can be probed more easily with experimental tools, the proposed TJI system has significant differences with any of the currently developed production-intent or full production systems. It is not clear to the reviewer that there will be any validation the system at the CRF will be relevant to either a Mahle-style active system or to the passive pre-chamber systems available from a number of suppliers. It would be more productive to ensure that the test system was relevant and included some approach to understand the mechanisms that typically preclude use of the systems such as scavenging, fouling, and heat loss. The reviewer stated that fundamental investigations in this space would assist industry in pushing the state of the art, while investigations on a wholly different kind of pre-chamber system may not produce high-value results.

The reviewer would also like to see some comparison back to conventional ignition systems; a lack of fundamental understanding of TPI and TJI has not been the main barrier to adoption. The reviewer pointed out that cost, performance, and durability have proven to be difficult challenges even without a fundamental understanding. To that end, it would be productive to consider how more conventional ignition system technology compares to these advanced systems and what aspects of the physics of conventional ignition match or do not match those of the more advanced systems. This would provide a bridge for industry to make use of the wide body of knowledge on conventional systems towards the understanding and development of advanced systems.

Reviewer 2:

The reviewer commented that work on transient plasma discharge ignition system is very interesting and must definitely be pursued due to the increased importance of lean burn technologies for high-efficiency engines. The work on TJI is being pursued by industry for both gasoline and natural gas engines and it is not clear what will be achieved in the current project, apart from fundamental understanding. This reviewer felt that the work on plasma is very relevant and important for future engine development, but work on TJI can be downscoped.

Reviewer 3:

The reviewer appreciated the broad range of ignition studies and states these are, in general, useful to further understanding of ignition processes. However, it is not clear how the proposed TJI study is going to help make better engines.

Reviewer 4:

The reviewer said that the approach was shown clearly and encompasses a broad range. While all areas have importance, it would be nice to see more emphasis or results from engine tests to help quantify the potential impact of various igniter technologies.

Reviewer 5:

The reviewer suggested that the team identify a few relevant experiments that can aid in understanding of an advanced ignition system that can enable various combustion modes. Seems like a lot of effort is being spent on understanding fundamentals without having some idea of the potential benefit of the ignition system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented the ozone studies have shown good progress, with results which are both significant and aid the understanding of the physics of the TPI system. The reviewer found that the development of the diagnostics and use of the calorimeter appears to have required a pretty significant effort, with results that are showing value. The engine results and planning for the evaluation of the TPI and TJI systems do not appear to have made as much progress and the current plans do not appear to align as well with the project goals and especially the needs of industry. The reviewer is concerned that the progress measure may not look as good next year based on the current plans.

Reviewer 2:

The new optical diagnostics to measure oxygen (O_2) concentration that have been developed were very interesting to this reviewer and help with understanding the behavior of the transient plasma ignitor. However, the reviewer was unclear how this information will be used to help improve the ignitor or make a better engine.

Reviewer 3:

The reviewer said that both the quantity and depth of work is impressive. The reviewer would like to see more interpretation/conclusions to assess relative potential of various paths.

Reviewer 4:
The reviewer commented that the team should design experiments to quickly understand the potential of ozone to control CA50.

Reviewer 5:
The progress on the work has been satisfactory. However, the extension of lean limit was unclear from the presentation. The reviewer questioned whether the work can be extended to include high exhaust gas recirculation (EGR) dilution conditions. Improvements on the electrodes to eliminate early arcs and consistent plasma formation are impressive. The reviewer believed that because the work on TJI has not commenced, it is perhaps worthwhile to downscope the TJI work and to re-scope the effort for a broader assessment of plasma ignition system: air dilution, EGR dilution, applicability to multi-mode combustion and integration with dynamic skip fire (DSF), and durability and mechanisms of failure of plasma ignition systems. One of this reviewer's concerns is the presence of the cathode in the piston. The reviewer asked because pistons experience high temperatures, how durable is the cathode. The reviewer also pointed out what if there is soot accumulation at the cathode and how it impacts the ignition system.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found this to be effective collaboration. It is unclear on the value for retrofitting to allow CD. This seems like it would only change boundary conditions, such as trapped residual, slightly.

Reviewer 2:
The reviewer commented that this project has good collaborations.

Reviewer 3:
Per the reviewer, very good collaboration exists with several industry partners.

Reviewer 4:
The reviewer said that the team's collaboration has been really good with industry partners. If both VTO and SNL continue efforts on TJI, then the reviewer recommended including Mahle and Robert Bosch/Michigan State University as collaborators. Both Mahle and Bosch have different approaches to TJI.

Reviewer 5:
The reviewer said there appears to be good and productive collaboration with ANL on the modeling of the TPI system. The reviewer is surprised that there is no collaboration with Esgee Technologies though. Esgee's work, presented at Society of Automotive Engineers (SAE) World Congress, appears to be well-aligned with the effort in this project, and leveraging commercial tools as well as advanced model development within the DOE system seems like it would be valuable.

The reviewer is concerned that there is not enough formal collaboration with ignition system suppliers; Woodward, Denso, and others make passive pre-chambers, and Mahle has been talking about the active pre-chamber system for years. Some more formal collaborations with these companies would help to focus the work within the project to ensure relevance with industry needs.

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 TJI direction sounds reasonable, but more detail would be useful to understand focus. The reviewer questioned which various geometries are to be assessed.

Reviewer 2:
The reviewer referenced prior comments, and expressed uncertainty that the plans for TPI or TJI truly get at what industry needs to be able to develop systems which could be considered for production. The reviewer said there is a large hole in the plans for actually demonstrating the improvement in engine performance and efficiency enabled by these systems, including showing that the energy required to run the systems is more than paid for with the improved performance/efficiency. If that basic metric cannot be achieved, then the rest of the work is not all that useful. The reviewer has not seen enough independent results to date that convinces the reviewer that these systems will enable combustion system developments that move the bar far enough compared to other options available at lower cost/complexity.

Reviewer 3:
The reviewer stated that experiments should be conducted to understand how the pre-chamber cavity is scavenged. Traditionally, not being able to scavenge the pre-chamber has been one of the most significant barriers to pre-chamber ignition technology.

Reviewer 4:
The reviewer commented that future proposed work (except for the TJI work) looks really good. The synergy of plasma ignition system and DSF is extremely interesting and the team should definitely pursue this.

Reviewer 5:
The reviewer opined that the proposed detailed work on pre-chambers may not contribute to improved engine performance. The reviewer commented that the proposed geometry is not relevant and it is not clear what questions will be answered. This work will not address the known barriers to pre-chamber implementation such as scavenging in a running engine, deposits in the pre-chamber, durability of the nozzle holes, heat loss from the pre-chamber, and cold starting performance.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer found this work to be very critical, particularly at this juncture, as more and more lean combustion systems will be put into the market in the future for enabling high-efficiency engines. Various alternative ignition systems have been proposed in the past and none of them have made it to the mass market. This project can enable the penetration of plasma ignition systems into the mass market in the future. The reviewer considered this very timely work.

Reviewer 2:
The reviewer stated that this project provides knowledge base for advanced LTC or mixed mode combustion systems across a broad range. The reviewer considered that this could be key for efficiency and emissions of future combustion systems.

Reviewer 3:
The reviewer commented that this work, to understand the ignition process, is relevant for engine designers to improve future engines.

Reviewer 4:
This project advances the state of the art in ignition technology needed for dilute, lean, and LTC combustion. The reviewer stated that all of these have potential in increasing engine fuel efficiency and reducing petroleum usage.

Reviewer 5:
The reviewer remarked this project does support the DOE objectives for enabling LTC and lean dilute SI combustion. But the reviewer questioned how well the project supports those objectives, particularly with respect to how easily industry could make use of the results.

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 a sharper focus for 2018 on TJI and one other system, unless further funding is available. The reviewer considers effort on CD a distraction.

Reviewer 2:
The reviewer remarked the budget and resources appear to be adequate for producing useful results. The reviewer stated that there needs to be a refocusing of some of the effort and for the project team to bring in additional industry collaborations that will ensure the relevance of the results generated.

Reviewer 3:
The reviewer found the project adequate relative to the resources for the project to achieve the stated milestones in a timely fashion.

Reviewer 4:
The reviewer questioned whether resources can be better utilized if each concept is serially investigated with an eye for providing more impactful information to industry, such as completing TPI before getting into TJI.

Reviewer 5:
The reviewer commented that FY 2018 funding of $920,000 seems sufficient. However, the reviewer would like to see that future work is well-aligned with resources as the project is accelerating more experimental work. In that regard, the reviewer would like to see milestones revisited for relevance.

Presentation Number: acs010
Presentation Title: Fuel Injection and Spray Research Using X-Ray Diagnostics
Principal Investigator: Christopher Powell (Argonne National Laboratory)

Presenter
Christopher Powell, 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 and well-planned.

Reviewer 1:
The reviewer stated that the approach to this work is good. Acquiring high-quality quantitative data that is then quickly shared with the combustion and spray community is excellent. This is demonstrated by the high use of this project's data as reference and validation in the computational literature.

Reviewer 2:
The reviewer found that the approach outlined in the presentation is good. In particular, the investigation into flash boiling is interesting and will be good for further comparison with simulation and other experiments within the ECN. The X-ray diagnostic provides unique data that adds value to the overall understanding of fuel sprays. It appeared to the reviewer that an improvement may be adding a simultaneous diagnostic that can image the fuel vapor, so that a more thorough characterization of spray processes can be done in these tests. However, that may not be physically possible at the X-ray beamline.

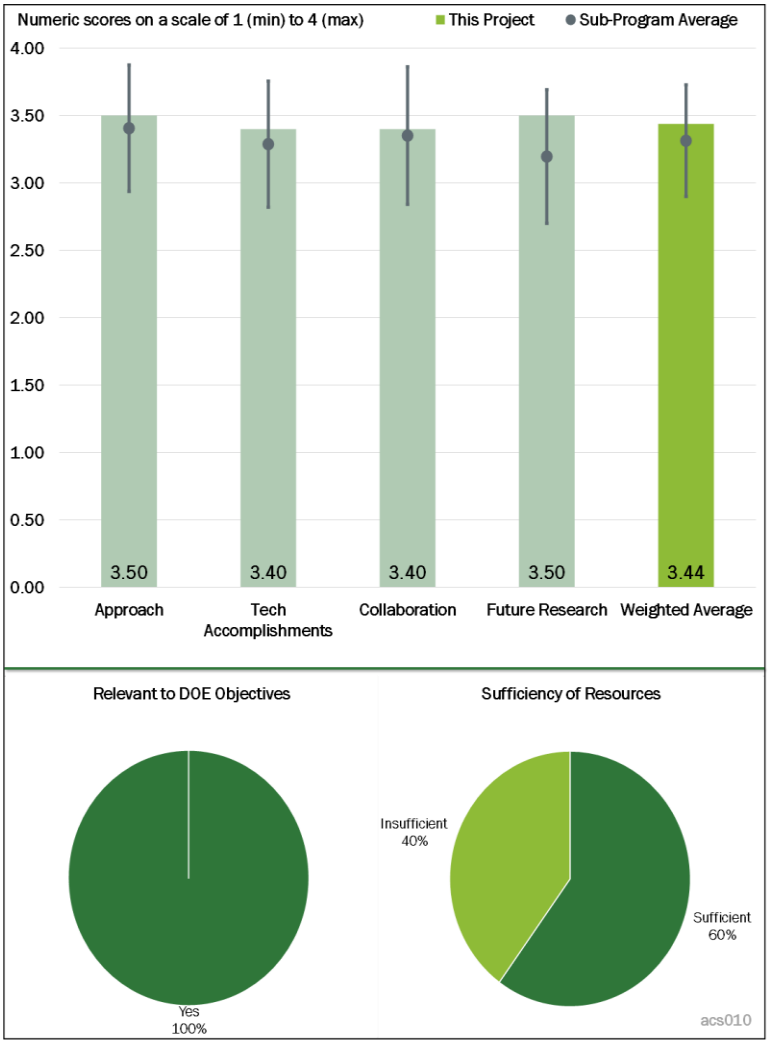

Figure 1-6 - Presentation Number: acs010 Presentation Title: Fuel Injection and Spray Research Using X-Ray Diagnostics Principal Investigator: Christopher Powell (Argonne National Laboratory)

Reviewer 3:
The reviewer found that this project continues to supply important near injector fuel behavior quantitative data that otherwise is experimentally difficult to obtain. It is providing important cavitation quantitative and qualitative data for further understanding near injection spray behavior and understanding the influence of nozzle finishing on the aforementioned cavitation phenomenon. The reviewer said that if it has not been addressed to date, two possible suggestions for widening the approach are first, to include wider varying injection pressure and nozzle design experimental work; and second, explore possible multiple-hole nozzle experiments to explore spray to spray effects.

Reviewer 4:
The reviewer commented that the project is well-designed and well-planned.

Reviewer 5:
The reviewer considered the approach clear. However, a project plan would be helpful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The progress and accomplishments on this project are strong, also indicated by the heavy use of this project's data in the ECN and spray communities. The reviewer stated that nowhere else can near-nozzle sprays be imaged with sufficient quantitative quality and the linking of the near-nozzle spray behavior to internal flow is invaluable. The link between diesel nozzle geometry, flow, cavitation, and near nozzle spray is very clear and can easily help industry justify actions to change physical hardware geometry. The reviewer was not entirely clear how close the experimental conditions were to engine conditions. Any attempts to align injector and ambient pressure and temperature with engine boundary conditions would likely be very valuable, as many times spray and injector behavior change. The progress on the diesel injector and sprays seems to be more mature than the GDI sprays. The reviewer was unclear how much progress was made on the GDI sprays relative to the objectives for FY 2018.

Reviewer 2:
The reviewer said that the technical accomplishments are good and have provided some unique and valuable data. The fact that the project focuses on processes occurring both inside and outside the injector provides additional insight, and this work should continue. The reviewer recommended the project team should be clearer about providing uncertainties of their measurements in future presentations. The reviewer commented that this was requested during the question period and is an important part of reporting quantitative results, particularly from such a complicated technique. Also, it would be good to know what the detection "floor" is for this technique, particularly in the case of flash boiling where there may be regions with very disperse and/or small droplets.

Reviewer 3:
The reviewer found that the use small-angle X-ray scattering method to measure the near-nozzle surface area provides useful information because traditionally quantitative information near-nozzle is very difficult to obtain due to the denseness of the spray. However, it could be even more useful if the surface area can be converted into droplet size distribution as claimed in the milestone accomplishment.

Reviewer 4:
The reviewer pointed out that much work was completed within the last year for both flash boiling exploration effects and in comparing sharp and rounded edge entry nozzles. The reviewer suggested further studying fuel injection pressure and nozzle opening period effects on that latter nozzle study.

Reviewer 5:
The reviewer found Slide 19 to be clear. A possible improvement could be calling it "Technical Accomplishments."

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found Slide 15 to be clear.

Reviewer 2:
The reviewer found that collaboration on this project can be represented as excellent by the active involvement with ECN, industry, and computational researchers. Everyone wants APS spray and injector experimental data for relevant spray, cavitation, and combustion work. This project is one of the top DOE funded combustion-spray projects and has direct and long-lasting impact to engine and fuel system OEMs. Please continue strong support and resource commitment to this work.

Reviewer 3:
The reviewer noted that flash boiling spray for GDI is of great interest, especially the multicomponent fuel effects on the flash boiling process have not been systematically studied in the past. There are a few groups within ECN currently performing flash boiling experiments using different diagnostics tools. A better collaboration and coordination will be very beneficial.

Reviewer 4:
The reviewer said that coordination with the ECN and teams doing simulation is adequate. It would be good to see more substantial collaboration on two fronts. First, the collaboration with neutron imaging at ORNL was only briefly mentioned, despite the neutron and X-ray diagnostics being important counterparts. Second, and more importantly, the collaboration with ANL's work on modeling injector degradation through cavitation (S. Som's work) should be strengthened, particularly as the simulations begin to identify the physics of injector degradation. Comparing the experimental data with the results of simulation will be critical, and hopefully the flow of information does not just go one way, and that a back-and-forth collaboration can be established in order to parse out the controlling physics. The reviewer highly encouraged collaboration with industry on this issue.

Reviewer 5:
The reviewer commented that this project has excellent collaboration including, most importantly, linkage to the engine combustion network.

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 the future work proposed by this project is outstanding. Specifically, cavitation erosion is a real barrier to fuel injector designs and operation that can increase engine efficiency and reduce emissions. This is greatly aligned to the needs of HD OEM and fuel system manufacturers. Gaining these erosion data would again be invaluable in conjunction with the flow cavitation data. Also, moving toward understanding real injector variation through used samples of many injectors is a very good step at helping to engineer the real variation. The reviewer commented that the inability of the near-nozzle diagnostic to measure wide-angle, multi-hole diesel fuel injectors is an area that could be investigated further. Alignment to real in-engine injectors and boundary conditions would produce yet another level of achievement and relevance, because this is commonly what OEMs need to be able to predict with computations.

Reviewer 2:
The reviewer said the proposed future work is also promising, particularly the work on near-nozzle fuel density and spray breakup. This is an area where this diagnostic provides unique data and insight. The reviewer suggested that the project team should continue to seek out these unique contributions, not just providing geometries for simulation and data for comparison to simulation. The insights gained into spray break-up in their past work have been very important, and so the reviewer encouraged the project team to continue looking for fundamental questions to answer, in collaboration with both academic and industry partners, where these unique data can be transformational.

Reviewer 3:
The reviewer said that the future work list is quite exhaustive. The reviewer suggested ensuring future nozzle comparison experiments include widely varying injection pressure and nozzle opening period time effects.

Reviewer 4:
The reviewer considered Slide 18 to be clear.

Reviewer 5:
The reviewer commented that the plan seems effective.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
According to this reviewer, the insight gained into spray processes from this unique diagnostics is extremely relevant to DOE goals regarding fuel sprays and advanced combustion modes.

Reviewer 2:
The reviewer commented this is truly a basic research tool that supports other research teams that are working on better understanding the role of near-spray flowfield on emissions formation and engine performance. The reviewer said that it is wonderful to see after nearly 20 years of the onset of this proposed facility and the struggles to validate this tool that it is consistently available to aid the community in better understanding spray behavior of DI diesels and DI gasoline engines during the last decade or so.

Reviewer 3:
The reviewer stated that this project clearly supports the DOE objectives because it enables science-based understanding of injection systems and sprays that are fundamental to engine efficiency and emissions reduction.

Reviewer 4:
Per the reviewer, spray characterization by X-ray is relevant to the DOE and this industry.

Reviewer 5:
The project provides valuable data for DOE national laboratories, industries, and universities.

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

Reviewer 1:
Considering how valuable this project is to enabling high-efficiency and low emissions combustion systems, the reviewer stated the belief that the resources and funding level in FY 2018 are insufficient. This project could easily be increased in scope and funding to allow acceleration of the value. The reviewer recommends considering increasing funding to allow the project to push towards work in as-close-as possible engine boundary conditions, and the described future work.

Reviewer 2:
For this reviewer, the reduced spending rate in FY 2018 is concerning, particularly given the uniqueness of this facility. The reviewer commented that the funding levels should be maintained in order to continue the valuable work being done by this team.

Reviewer 3:
The reviewer stated that the project team has sufficient resources.

Reviewer 4:
The reviewer stated that it looks okay, but the reviewer does not believe to be in an adequate position to judge this.

Reviewer 5:
The reviewer had no comments.

Presentation Number: acs011
Presentation Title: Advances in High-Efficiency Gasoline Compression Ignition
Principal Investigator: Steve Ciatti (Argonne National Laboratory)

Presenter
Chris Kolodziej, Argonne 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 and well-planned.

Reviewer 1:
It appeared to the reviewer that the researchers had a well thought-out approach to the research allowing solutions to the problems limiting gasoline compression ignition (GCI) engines. The researchers have made great strides in the research toward these goals.

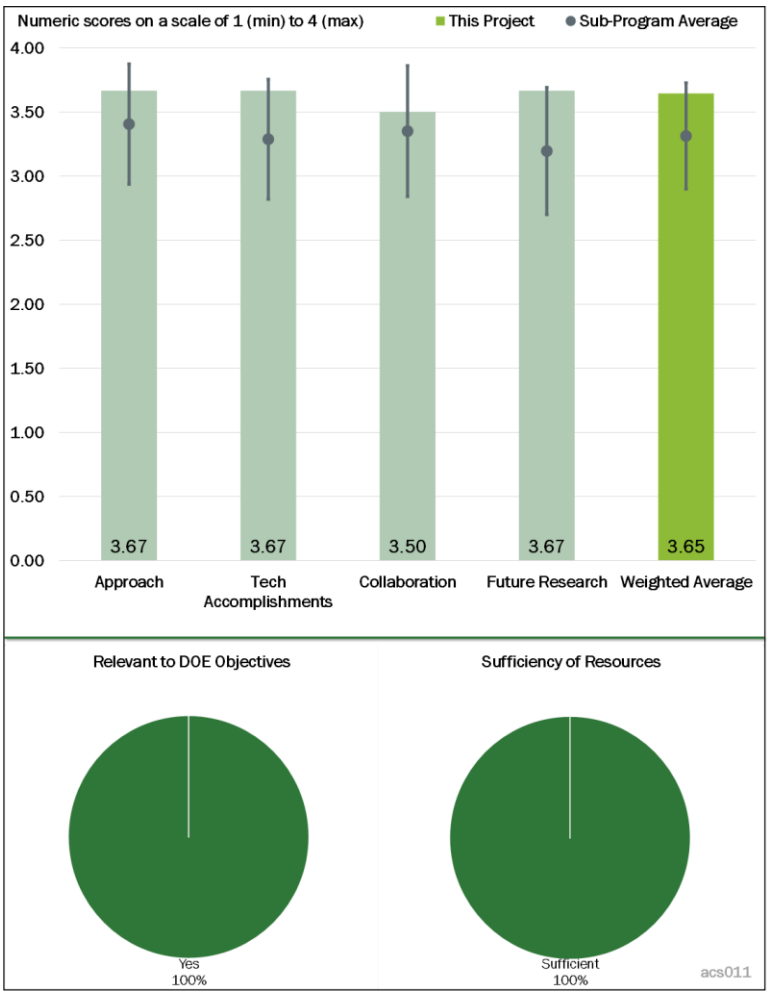

Figure 1-7 - Presentation Number: acs011 Presentation Title: Advances in High-Efficiency Gasoline Compression Ignition Principal Investigator: Steve Ciatti (Argonne National Laboratory)

Reviewer 2:
The reviewer commented that the approach could be improved by including a summary of noise and control factors. There is a need to identify noise factors that have significant impact on controlling combustion phasing. Variability in fuel quality also being a potential issue. The reviewer questioned whether the approach will need to employ combustion pressure feedback or if the intent is to identify an open loop calibration approach. The reviewer noted that transitioning from LD to HD is appropriate considering the guidance from the ACEC.

Reviewer 3:
The reviewer found this approach to be clear and relevant.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said accomplishments of this project are excellent. The researcher has shown the ability to achieve high levels of engine efficiency with low combustion noise and low emissions. The approach to achieving these high levels of efficiency is laid out clearly and is achieved over a broad range of speeds and loads.

Reviewer 2:
The reviewer found that the project has made reasonable progress, considering the transition in the project team and issues with equipment damage.

Reviewer 3:
The reviewer commented that the accomplishments are clear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the project appears to be ramping up collaborations with HD OEMs.

Reviewer 2:
This reviewer noted that this project has an excellent level of inter-lab collaboration and industry collaboration. Although, it has less academic collaboration.

Reviewer 3:
The reviewer stated that the collaboration is clear.

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 with the LD OEM's push for multimode combustion engines, the move to HD research is timely. The reviewer said that the multimode combustion will not need nearly as much research and because the research has already been performed across a broad range of speeds and loads, this research will be beneficial to the HD industry, which is looking for a full engine map solution to their problems.

Reviewer 2:
The reviewer said that GCI at high load is very interesting. The reviewer recommended the project team consider using more ethanol, up to 85% ethanol blend with gasoline (E85), if possible.

Reviewer 3:
The reviewer considered the transition to HD is appropriate.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked this project is a novel approach to improving the fuel efficiency while lowering the engine emissions of HD engines.

Reviewer 2:
The reviewer commented that GCI at high load is important to improve IC engine efficiency in the real world.

Reviewer 3:
The reviewer stated that it supports objectives if barriers are overcome.

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 looks okay but the reviewer does not believe to be in an adequate position to judge this.

Reviewer 2:
The reviewer said this project has sufficient funds for research at ANL. However, to the reviewer it appeared that the project's funds will not allow for collaboration with outside universities or national laboratories.

Reviewer 3:
The reviewer considered this project's resources to be sufficient.

Presentation Number: acs012 Presentation Title: Model Development and Analysis of Clean and Efficient Engine Combustion Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

Presenter
Russell Whitesides, Lawrence Livermore 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 and well-planned.

Reviewer 1:
The reviewer said that this laminar flamelet approach provides a conceptually useful way to understand the turbulent flame structure in the combustion chamber of an engine. The reviewer commented that this should provide both a useful way to understand the combustion for a range of combustion types, and allow the transition between different types of turbulent combustion.

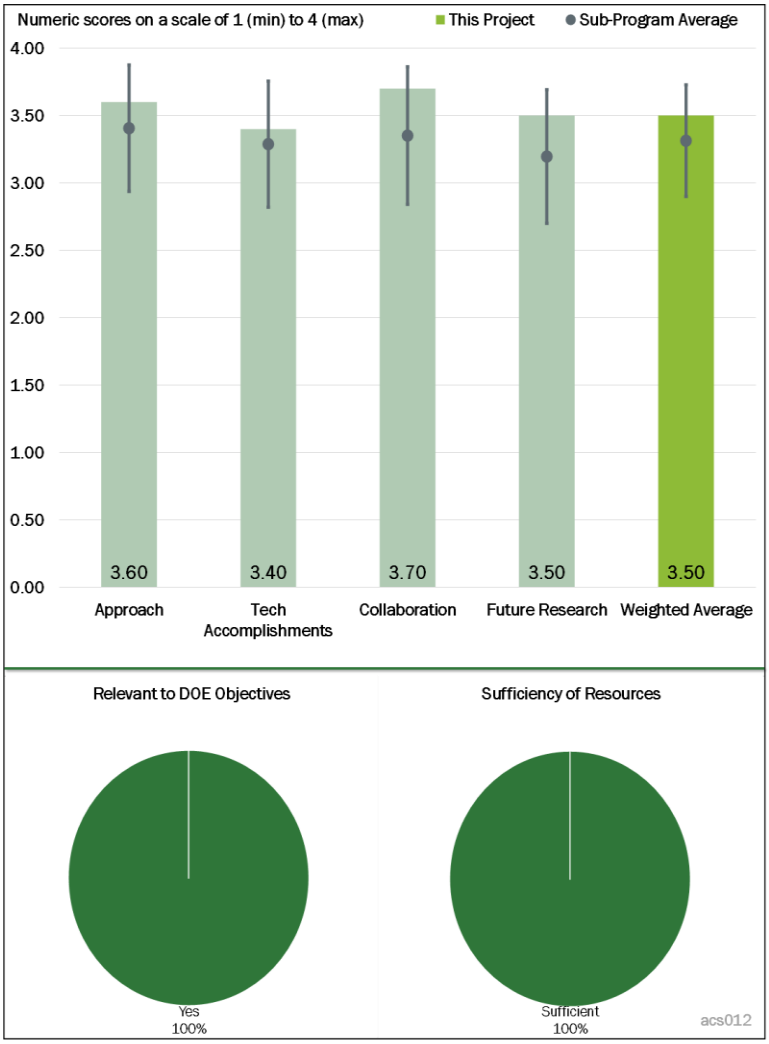

Figure 1-8 - Presentation Number: acs012 Presentation Title: Model Development and Analysis of Clean and Efficient Engine Combustion Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

The reviewer also said that the numeric technology shown here is very impressive. It takes a difficult-to-use turbulent flame model and makes it accessible. Including turbulent diffusion in the laminar flame calculation is great. The reviewer pointed out that in the past, it was not really possible. What is typically viewed as wrinkled turbulent flames should be best treated by this approach. The reviewer suspected that thick flame brush turbulent flame fronts will probably cause major increases in the computational demand. Finally, in spite of all the positives, the computational demands for this technology are significant. The reviewer is not sure any of the OEMs can or will have access to this level of computing resource.

Reviewer 2:
The reviewer remarked the project team is doing a great job in having the approaches aligned well with the barriers. One point is that it may be nice to have an open platform CFD code to implement and test those improvements. The reviewer pointed out that commercial codes are often not appropriate for use in academia.

Reviewer 3:
The reviewer stated that CFD with the detailed kinetics is important for the future high-fidelity engine combustion modeling; however, the detailed combustion mechanism also significantly increases the

computational cost. Due to the sparse nature of the kinetics matrix, great potential exists to accelerate the calculation. The reviewer stated that improving the solver is critical.

According to the reviewer, the project team could also consider other approaches to accelerate computational speed. For example, reducing the reaction mechanism on the fly, while keeping sufficient accuracy. The laminar flame speed solver will facilitate researchers to validate reaction mechanisms.

Reviewer 4:
The reviewer found that this is very good work being pursued by LLNL and that it is very timely. Advanced and efficient computation of chemistry and combustion calculations is extremely important for full-geometry CFD simulations.

Reviewer 5:
The reviewer would appreciate more details and examples on transfer to industry CFD toolsets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that the technical accomplishments and the progress in the project are excellent. Zero-order reaction kinetics (Zero-RK) and mechanical checker availability to the larger research community is crucial. The plot of computation time for computations with SAGE and Zero-RK with CVODE solver and Zero-RK with SEULEX solver are extremely encouraging. The reviewer said that the laminar flame speed match with experimental data is very encouraging. The project team has performed very well.

Reviewer 2:
The reviewer stated that comparisons with engine measurements (Slides 14 and 15) are evidence that the approach has predictive value.

Reviewer 3:
The reviewer appreciated the work on laminar flame speed, especially as could be used towards knocking behavior.

Reviewer 4:
Per the reviewer, good progress has been made in accelerating detailed kinetics in engine CFD, modeling ECN spray, and predicting laminar flame speed.

Reviewer 5:
There appeared to the reviewer to be solid progress overall. The reviewer suggested that it would be great to see how accuracy compares over solvers (i.e., SAGE to CVODE to SEULEX) in Slide 9. Also, it would be nice to see the measured heat release rate (HRR) and engine-out emission values in Slide 14.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer considered this an excellent collaboration with national laboratories, OEM, and industry.

Reviewer 2:
The reviewer commented that the collaboration list makes an excellent stream starting from fundamentals to end user applications.

Reviewer 3:
The reviewer said that collaboration with groups ranging from computing hardware and software to engine measurements is very encouraging. The reviewer commented that there really was not time to evaluate how close those collaborations actually are.

Reviewer 4:
The reviewer pointed out that collaboration across team members has been crucial to the success so far. The reviewer suggested collaborating with OEMs other than GM. Also, the reviewer questioned whether there is a plan to integrate the Zero-RK chemistry solver with CONVERGE CFD or other CFD software that are used in industry. The reviewer said this will magnify the project's impact.

Reviewer 5:
The reviewer noted broad collaboration. However, the project presentation could elaborate how it was useful (changed focus or accelerated progress).

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 the focus on improving the computational speed addresses what the reviewer views as the primary barrier to applying this technology to the development and application of advanced combustion strategies.

Reviewer 2:
The reviewer commented the future work on data science/machine learning to optimize solver performance is very nice. The reviewer suggested that the project team should also investigate machine learning methods for adaptive chemistry mechanism reduction, if possible. The reviewer pointed out this work will mitigate some of the issues that have been plaguing CFD simulations, e.g., full cycle and full mesh CFD simulations with detailed multi-component fuel chemistry (and PAH chemistry for soot model predictions) can be enabled with these methods.

Reviewer 3:
The reviewer commented that the future research plan does not seem very concrete. Perhaps it is due to the merge of the program. It is going to be nice if a way to evaluate the performance of the new developments out of CONVERGE platform is laid out.

Reviewer 4:
The reviewer liked the idea of conducting more research on uncertainty quantification and sensitivity analysis. The presentation lacked the details of how to combine machine learning for solver optimization. The reviewer is looking forward to learning more next year.

Reviewer 5:
The reviewer questioned what a significant increase in funding would allow.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer found that, yes, the project is well-aligned with DOE objectives. All the development will directly serve the community to better understand and develop advanced combustion systems.

Reviewer 2:
Per the reviewer, this work is very relevant to the DOE objectives and is very timely in nature. The progress of the project team is very impressive.

Reviewer 3:
The reviewer said that the capacity to predict the time dependent flame structure and the instantaneous emissions will dramatically assist in the development of the optimum low-emission combustion technologies.

Reviewer 4:
The reviewer commented that faster, higher fidelity models, with transfer to industry toolsets, have a direct path to lower carbon dioxide (CO_2).

Reviewer 5:
The reviewer remarked that high-fidelity chemical kinetics modeling is critical for future advanced ICE development. The reviewer stated that this project supports the DOE objectives of reducing fuel consumption.

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

Reviewer 1:
According to the reviewer, the project team has sufficient resources to achieve the stated milestone.

Reviewer 2:
The reviewer commented that the resources do seem sufficient.

Reviewer 3:
The reviewer said that the FY 2018 funding of $600,000 is very reasonable for modeling/simulation work.

Reviewer 4:
The reviewer stated that there is no evidence that this work is funding limited.

Reviewer 5:
The reviewer questioned what amount of funding is for central processing unit (CPU) access.

Presentation Number: acs013
Presentation Title: Chemical Kinetic Models for Advanced Engine Combustion
Principal Investigator: Bill Pitz (Lawrence Livermore National Laboratory)

Presenter
Bill Pitz, Lawrence Livermore 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 and well-planned.

Reviewer 1:
The reviewer pointed out how detailed fuel chemical kinetic models are the foundation for developing advanced engines. The models developed by the project team have been widely used by OEMs, research institutes, and universities across the world for combustion simulation. The team is also making significant progress in improving and adding models every year. The reviewer stated that the project is very well-designed and feasible.

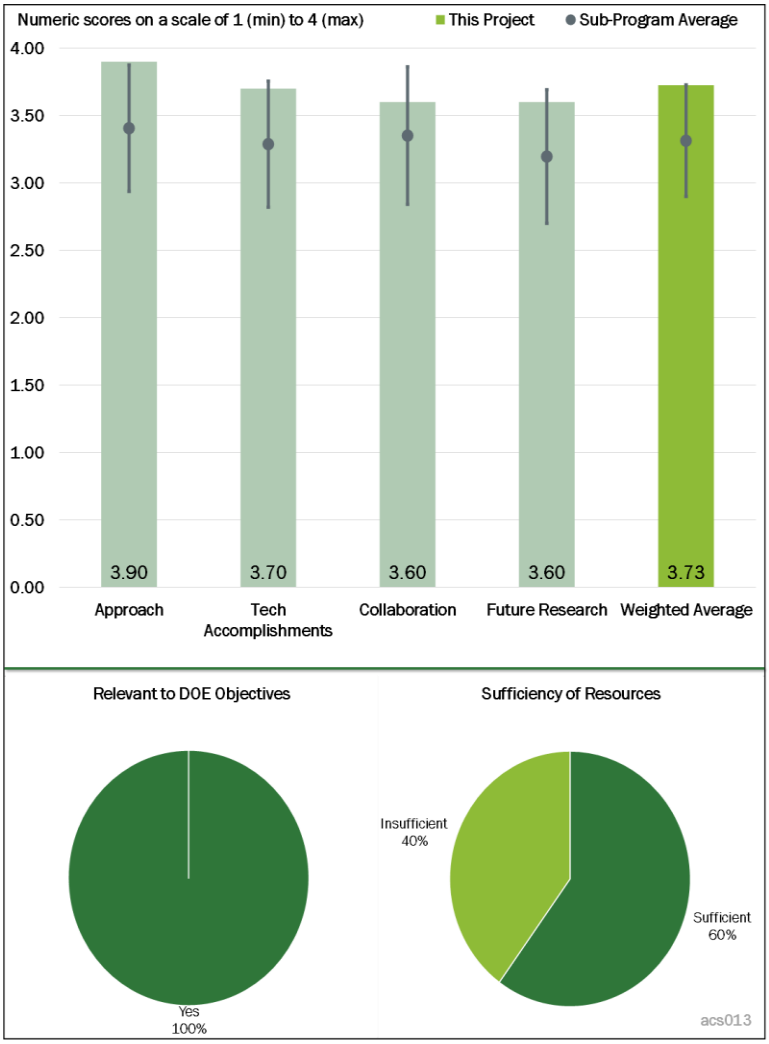

Figure 1-9 - Presentation Number: acs013 Presentation Title: Chemical Kinetic Models for Advanced Engine Combustion Principal Investigator: Bill Pitz (Lawrence Livermore National Laboratory)

Reviewer 2:
The reviewer found this project has quality research as usual. It is good to focus on developing mechanisms for accurately representing dilute combustion (i.e., EGR).

Reviewer 3:
The reviewer said that the project team completed project milestones. The kinetic models developed or improved in this project addressed the technical barriers on engine efficiency and emissions. The project is well-designed and fit extremely well with the other efforts in the VTO programs.

Reviewer 4:
The reviewer stated that this study represents the only means to approach engine performance barriers from a fundamental point of view.

Reviewer 5:
The reviewer said that the objectives of this project are to develop kinetic models for gasoline, diesel, and next-generation fuels including those mixed with ethanol (which is widely used). The project team has pursued

this line of work for a long time and is expert in this field. In the reporting period, the focus was on diesel surrogates and using RCM data as a means to compare predicted and measured results. Additionally, gasoline surrogates are investigated and new surrogate data are reported.

The reviewer remarked that the project is very-well developed and the project team has an excellent grasp of the subject of kinetic mechanism development. The approach this year focuses on gasoline, diesel, and ethanol blends. It develops reduced mechanisms appropriate for CFD simulations and uses the models to predict new data obtained with the project team's collaborators. The reviewer pointed out how many gasoline surrogates have been presented in the past. Here, four and five component surrogates are developed for gasoline and diesel. The reviewer commented that it would be good if the project team could state what differentiates the various surrogates developed in this latest effort from past work on gasoline and diesel surrogates. For example, concerning diesel, Philippe Dagaut and co-workers have proposed a three-component surrogate for diesel (decane/propylbenzene/propylcyclohexane). The reviewer questioned how predictions compare with this (or other) diesel surrogates.

The reviewer pointed out that as the number of surrogate components increases there will be point of diminishing return. The computational difficulties will increase, especially when spray injection is considered. The reviewer questioned whether the project team offers any insights into this potential concern. Ultimately, how the surrogate performs in detailed models of in-cylinder processes is important. Hopefully, future presentations will include such comparisons with those that the project team is collaborating with. The reviewer noted that a significant problem is formation of particulate matter. The project team addresses this by including predictions of PAH mechanisms. The reviewer would like to see any insight about how the kinetics perform when predicting more global features such as soot volume fraction.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said the team made excellent progress on gasoline and surrogate chemical kinetics. The results show that the project is on track to develop kinetic mechanisms that industry and academia can use to improve engine efficiency and emissions. Furthermore, the work on aromatics is very important.

Reviewer 2:
The reviewer said that the team has made significant progress in developing models for key gasoline and diesel surrogate components, and improving aromatic and preliminary PAH mechanisms.

Reviewer 3:
The reviewer remarked the current limitation to this approach is the amount of kinetic data that need to be generated. Ideally there should be a program designed just to generate, first experimentally, then theoretically, the kinetic data necessary to improve kinetic models.

Reviewer 4:
The reviewer commented that progress appears similar to past years and commensurate with funding.

Reviewer 5:
The reviewer pointed out that a range of surrogate components were identified for gasoline surrogates. The results presented gave high-fidelity predictions for pressure versus time in an RCM (Slide 9) compared to RD587 early on, though this was a less satisfactory agreement at a later time. The reviewer questioned whether the disagreement reveals uncertainties in the kinetic rates, rate parameters, properties, the model itself, etc. Similarly, the fuels for advanced combustion engines (FACE) comparison in Slide 10 also show varying degrees of agreement. On the log scale, the difference can be as high as a factor of two. The reviewer questioned what the strategy is for closing the gap, or what the possible reasons are for the differences.

The focus of the problem considered is developing combustion kinetics of complex fuel systems. The reviewer questioned whether there are other inputs to models that could influence predictive performance as well, such as properties (e.g., gas diffusion coefficients), or submodels involved in the simulation (e.g., turbulence), etc. The reviewer also questioned if there is a way to separate these aspects, properties from kinetics that could guide the project team's effort and provide additional guidance on what best to focus on in the development of improved surrogates. The reviewer noted how some comparisons were shown for shock tube data at 220 atm and questioned whether engines operate at such conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said the topic is very complex and it would not work without the excellent collaboration and coordination across the project team. The reviewer found that results of the project confirm that observation.

Reviewer 2:
The reviewer observed excellent collaboration with national laboratories and universities. The reviewer knows the models are also used by OEMs, either directly or in-directly, as they are basically used as benchmarks to develop the reduced mechanisms for engine simulation.

Reviewer 3:
The reviewer remarked the project includes a number of collaborators that are well integrated with the project team's efforts. SNL is a strong choice for engine studies, ANL a strong choice with RCM data, various universities, etc. The reviewer pointed out the good thing about these collaborations is that they provide quantitative interactions and data that the project team needs and uses to advance the work.

Reviewer 4:
The reviewer commented that this collaboration looks solid, and expressed interest in seeing more of the evidence showing how the mechanisms are employed. Perhaps focus on an example as a case study for 2019.

Reviewer 5:
The reviewer suggested that this collaboration should be expanded to include an ignition delays database and modeling from Stanford University.

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 future work is well-developed, including more research on surrogates that better represent gasoline, validation, PAH soot models, and more collaborations with the modeler. There is a focus on RCM data. The reviewer also suggested that consideration should also be given to showing data from other combustion configurations. Finally, assessing the various gasoline surrogates would also be useful.

Reviewer 2:
The reviewer said the proposed future work addresses most of the barriers for current fuel or surrogate kinetic models. Future work on aromatics kinetic models is extremely important for correct soot modeling.

Reviewer 3:
The reviewer noted the project is well-planned for future research, especially for PAH soot kinetic model, and reduced versions of gasoline and diesel surrogates for real engine development.

Reviewer 4:
The reviewer recommended a continued focus on dilute combustion SI gasoline.

Reviewer 5:
The reviewer said this study should not only focus on surrogate mixtures. Before moving into complex mixtures, it is necessary to identify the key chemical reactions that control ignition delays, and link the respective chemical reactions to specific fuel molecules.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer considered these data as crucial in simulating engine performance.

Reviewer 2:
The reviewer stated that, yes, from a broad perspective the project does support the overall DOE objectives. Surrogates are the essential ingredients to engine simulation, without which it would not be possible to predict engine performance.

Reviewer 3:
The reviewer said high-fidelity chemical kinetics models are critical for future advanced ICE development. The project supports the DOE objectives of reducing fuel consumption.

Reviewer 4:
The reviewer commented that if the focus remains on dilute combustion, then the project is relevant.

Reviewer 5:
The reviewer pointed out it is difficult to achieve the goals on engine efficiency and emissions without accurate chemical kinetics.

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 unclear how the project team manages to produce such good results with such a low budget, unless this work benefits from other funding sources as well.

Reviewer 2:
The reviewer said that the project team has sufficient resources to achieve the stated milestone. RCM for diesel surrogate components could be challenging. Also, the reviewer is not sure what data will be used for PAH/soot model validation. The reviewer is looking to learning more about these next year.

Reviewer 3:
The reviewer said there should be a unified program to develop and build this essential database, just like those that exist for stratospheric ozone and climate studies. The reviewer commented that there is not enough knowledge contribution from experts in chemical kinetics.

Reviewer 4:
The reviewer said that the funding appears to be sufficient. Additionally, the project team did not comment on a need for increased funding.

Reviewer 5:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Presentation Number: acs015
Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes
Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

Presenter
Jim Szybist, Oak Ridge 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 and well-planned.

Reviewer 1:
The reviewer considered thermochemical recuperation an interesting approach which, if successful, is superior to the dedicated EGR approach. The researchers have shown the reasons why this approach gives improvement through thermodynamic analysis. This helps direct the approach they are taking.

Reviewer 2:
The reviewer stated that the project addresses reformation for additional dilution, which is a viable path to higher efficiency. This is a good combination of experiments and fundamentals. The reviewer said additional efforts on practical limitations of concepts would be useful, such as load transient load control, cold start feasibility.

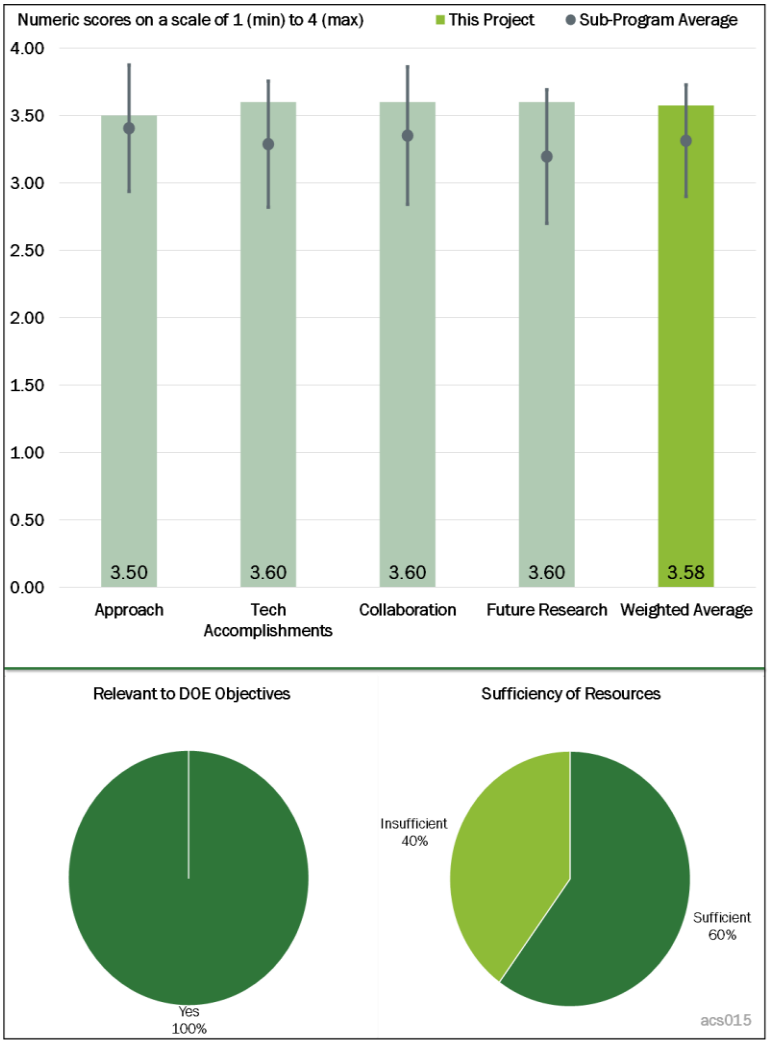

Figure 1-10 - Presentation Number: acs015 Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

Reviewer 3:
The reviewer noted the approach includes experiments to better characterize catalysts for more efficient reforming. Three areas are targeted: thermal management associated with waste heat recovery through recuperation, incorporate EGR catalytic reforming (that produces syngas) which extends the EGR dilution tolerance, and efforts to simplify emissions control and cost complexity. The effort with cost control was a bit vague and the reviewer is unsure how this will be done.

The reviewer questioned the rationale for selecting the Umicore catalyst with the specifications noted in the presentation—2% Rh supported on aluminum oxide (Al_2O_3) and coated with zirconia-mullite substrate. The reviewer was interested in the rationale to selecting these particular catalyst parameters. The reviewer said the catalyst is incorporated into one cylinder (of a four-cylinder engine). The reviewer questioned whether this cylinder is a sort of sacrificial cylinder from which no power was derived. Also, the reviewer inquired what fuel the team used.

Reviewer 4:
The reviewer said that the project team is investigating manipulating gamma and fuel composition to increase engine efficiency. This is done by thermochemical manipulation of fuel and EGR. The approach using a novel catalyst and a dedicated cylinder for EGR was a unique way to overcome technical barriers to engine efficiency.

Reviewer 5:
The reviewer remarked sound chemical thermodynamic principles are being applied to investigate the viability of this concept.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed very good accomplishments. The analysis accurately delineates the various reasons for the benefits observed. It would be nice to show the amount of exhaust enthalpy being used to heat the catalyst, even though in the current configuration it would be reported as the external energy supplied to the catalyst by the laboratory set-up. The reviewer pointed out the researchers honestly present the challenges they are facing, like S contamination.

Reviewer 2:
The reviewer commented that gamma investigation very high value. More effort needed on catalyst efficiency over time; one hour, 100 hours, 300,000 miles, etc.

Reviewer 3:
The reviewer found that progress has been good considering the practical equipment failure challenges.

Reviewer 4:
The reviewer noted that productivity in the reporting period was excellent with three journal articles published in a prestigious journal. The papers provided details of different fuel compositions, reforming and energy balances, catalyst performance, brake thermal efficiency (BTE) gain, and comparisons with conventional EGR systems. The reviewer said the finding that re-forming with oxygen requires rich conditions is interesting. The units presented on some of the figures were a bit confusing, for example, “fraction of fuel enthalpy” could be better defined. The reviewer said some discussion of being unable to balance the load between cylinders could be useful. The reviewer questioned whether the presence of the thermocouples inside the catalyst has any impact on the measured temperature distribution from the inlet to the outlet of the exhaust.

The reviewer questioned what it is about increasing the RPM that causes the catalyst temperature to increase. In a broader context, it would be useful to do more than present cause and effect in the results but to try to explain what is happening. The effort is one of testing and evaluating, though extracting some physics is useful as well. The reviewer pointed out system modifications were made to enable in-pipe boosted operation. The effort appeared extensive. However, the rationale behind things like increasing the EGR cooler volume, incorporating a bank of flow controllers, and incorporating a rupture disk for more realistic boundary conditions was not clear. The reviewer questioned whether these modifications made on-the-fly or if there more to it, and questioned what caused the equipment failure and what lessons were learned.

The reviewer found that the CHEMKIN simulations on closed cycle thermodynamics for adiabatic conditions were interesting. The geometry of CHEMKIN is very different from the engine environment. The reviewer wondered if the CHEMKIN insights applicable to the present study, and if so why they are applicable. The reviewer also questioned why the project used iso-octane in the simulation and not a PRF (i.e., a mixture of heptane and iso-octane, for example).

Reviewer 5:
The reviewer said that while the project team had several technical accomplishments and showed that the novel approach using dedicated EGR and gamma manipulation had merit (1.5% efficiency improvement), there were several systems limitations that this approach did not account for. The project team does have a plan to overcome these limitations.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the team is working with a nice mix of interested stakeholders.

Reviewer 2:
The reviewer found this to be good collaboration. The reviewer questioned why, with so many comparisons to similar Southwest Research Institute work (but with key differences), they are listed.

Reviewer 3:
The reviewer remarked the project team had excellent and appropriate partners that they collaborated with.

Reviewer 4:
The reviewer considered that good collaboration exists with industry for its feedback and guidance.

Reviewer 5:
The reviewer said collaborators are appropriate and the collaboration with Umicore is essential. The reviewer questioned whether the project team has plans to collaborate with other catalyst manufacturers. The reviewer commented that it would be good to show closer links with some collaborators. The collaboration with Umicore is clear and the collaboration with the university is very good. OEM collaborations are important, though it was not clear to this reviewer what the OEMs say about the barriers that must be overcome before they will consider implementing the concepts of this project in a product line. The reviewer stated that more specifics would be helpful.

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 the project team had a well thought-out plan to overcoming the systems physical limitations. The project team showed what the systems limitations were and how they planned on overcoming them.

Reviewer 2:
Per the reviewer, future work seems to focus on the most salient aspects of the program.

Reviewer 3:
The reviewer stated that all the relevant barriers are being addressed in the future work.

Reviewer 4:
The reviewer said discussion of future work listed activities noted for flow reactor measurements, determining the extent of S deactivation, developing techniques to regenerate catalysts, and 3D modeling. The reviewer commented that the relevance of the one-dimensional modeling could be strengthened.

Reviewer 5:
The reviewer commented that given small funding, proposed future work seems almost too much. The reviewer questioned whether the end game to develop insight and understand catalysts or whether it is to truly commercialize a form of dedicated EGR.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that yes, certainly the goal of increasing fuel efficiency will be relevant to DOE's interests. In this project, the focus is on the thermodynamics of engine processes and minimization of thermal loss and catalyst performance for reforming.

Reviewer 2:
Per the reviewer, this project is a novel and well thought-out approach to improving engine efficiency while lowering emissions.

Reviewer 3:
The reviewer said improved engine efficiency is targeted, which will reduce petroleum use.

Reviewer 4:
The reviewer stated that this supports the roadmap to LTC.

Reviewer 5:
After listening to the presentation and reading the information in the slides, the reviewer is not so confident that this will be a viable approach to improving efficiency. However, evaluation of this concept is appropriate for a government laboratory. Whether successful or not, valuable learning will take place. The dissemination of the thermodynamic analysis alone represent valuable teaching for the stake-holder community.

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

Reviewer 1:
According to the reviewer, resources are only 40%-50% of comparable projects. The reviewer recommended more funding to accelerate research in this area recommended. There is a good track record of efficient spending.

Reviewer 2:
While not stated, it was apparent from the budget size and the technical limitations of the setup that the project team was limited by resources to optimize the approach. The reviewer stated that the researcher has plans to overcome these limitations.

Reviewer 3:
The reviewer commented that resources are sufficient to impact stated goals.

Reviewer 4:
The reviewer said as long as there are not too many experimental problems, the funding seems sufficient.

Reviewer 5:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Presentation Number: acs017
Presentation Title: Accelerating Predictive Simulation of Internal Combustion Engines (ICEs) with High-Performance Computing (HPC)
Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

Presenter
K. Dean Edwards, Oak Ridge 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 and well-planned.

Reviewer 1:
The reviewer said the approach of working with collaborators to push the limits of HPC by evaluating the computational performance of ever more detailed modeling efforts on realistic industry challenges is excellent.

Reviewer 2:
The reviewer commented that the project team is doing a great job in having the approaches aligned well with the barriers. The reviewer commented that it may be nice to have an open platform CFD code to implement and test those improvements. Commercial codes are often not appropriate for use in academia.

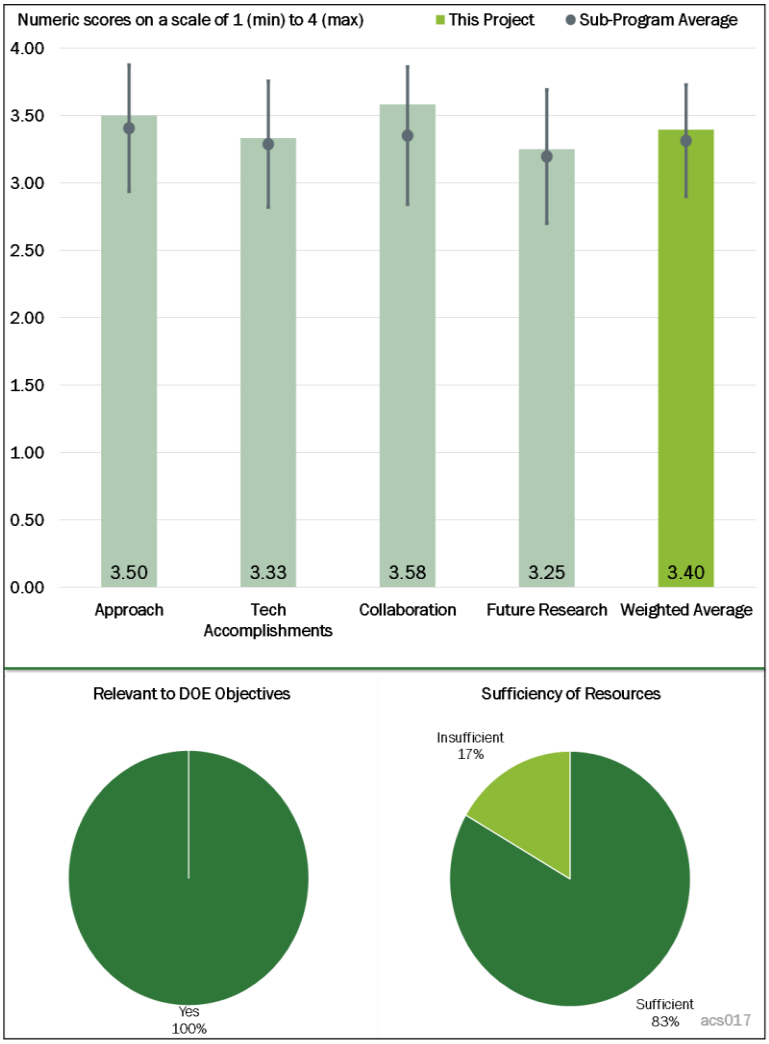

Figure 1-11 - Presentation Number: acs017 Presentation Title: Accelerating Predictive Simulation of Internal Combustion Engines (ICEs) with High-Performance Computing (HPC) Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

Reviewer 3:
This is an outstanding approach only possible through HPC capabilities at national laboratories. The project is addressing problems relevant to OEMs. The reviewer would like to see what can be done for transient cold start conditions with an eye towards predicting emissions. Assorted sub-models could be combined to predict test procedure emissions. Additionally, a combustion model could be used to establish boundary conditions at the exhaust valve. The reviewer described simulating the exhaust manifold, mixing, heat transfer, and chemistry as the gases move through the exhaust hot end, and turbocharger. Feedgas then enters the catalyst. The reviewer suggested including a catalyst brick model with chemistry to understand how the brick heats up and begins to convert. This entire model could then be used to optimize catalyst heating calibration, exhaust design, turbocharger/wastegate design, and catalyst design on a transient basis. The reviewer is excited to see the possible uses of this approach on full system level transient emissions.

Reviewer 4:
This project shows to industry what is possible by applying HPC to practical problems that industry is facing. HPC addresses the classic tradeoff between speed and accuracy.

Reviewer 5:
The reviewer stated that HPC computing in national laboratories is very important for industry.

Reviewer 6:
The project generally addresses some of the barriers to using HPC to improve combustion system design to reduce emissions and improve efficiency, particularly for smaller engines, especially SI. The reviewer did not see similar scale of effort to address the problems of HDD CI engines. The reviewer stated that more balance between the two would seem to be beneficial since it could be argued that electrification will likely target smaller vehicles first so long-haul, HD power will likely remain combustion-based in the longer term comparatively.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer found that the team has pursued and shown success in a broad range of realistic problems such as knock modeling, viral design, LES, and conjugate heat transfer (CHT).

Reviewer 2:
The reviewer stated that this is solid progress overall. The reviewer suggested that it would be great to see how accuracy compares over solvers (SAGE to CVODE to SEULEX) in Slide 9. Also, the reviewer commented that it would be nice to see the measured HRR and engine-out emission values in Slide 14.

Reviewer 3:
The reviewer said that this project is addressing OEM relevant issues.

Reviewer 4:
The reviewer pointed out that knock modelling is being conducted in conjunction with collaboration with Fiat Chrysler Automobiles (FCA). Virtual engine design and calibration is being demonstrated with increased simulation detail and predictive accuracy. This reviewer reported that the effect of increasing detail in chemical kinetic models on predictive accuracy as well as full-cycle simulations and CHT are being evaluated. The reviewer commented that there is still a way to go before emissions can be predicted with reasonable accuracy.

Reviewer 5:
The reviewer said that much of the work parallels capabilities already in place with at least some engine makers or reaching implementation with commercial tools reaching the market. The reviewer commented that the scale of design studies envisioned have already been surpassed by some engine companies as part of routine with automated optimization already in use to offload engineering resources in some areas.

Reviewer 6:
The reviewer found that Slide 4 is clear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the collaboration list makes an excellent stream starting from fundamentals to end user applications.

Reviewer 2:
The reviewer commented that this is excellent collaboration.

Reviewer 3:
The reviewer said that good collaboration exists with industry, other national laboratories, and CFD software suppliers.

Reviewer 4:
The reviewer commented that Slide 2 is clear.

Reviewer 5:
The reviewer saw collaboration with SI engine makers, but not at the same level for HDD CI engine makers. There is mention of contribution to the SuperTruck II team, but no details are presented as to what is to be accomplished and when.

Reviewer 6:
The reviewer referenced prior comments.

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 planned future work seem very much on target. The team will use the code to identify hotspots and autoignition locations. The reviewer questioned whether current capability could be extended to simulating cold start with an aftertreatment system.

Reviewer 2:
The reviewer remarked that proposed work is commensurate with funding. The reviewer would like to see this approach applied to more emissions systems level work for gasoline SI combustion.

Reviewer 3:
The reviewer stated that Slide 19 is good and clear.

Reviewer 4:
The reviewer said the work plan for the future is very good. The reviewer suggested continuing to move towards LES is good.

Reviewer 5:
The reviewer said the future research plan does not seem very concrete. The reviewer found that perhaps it is due to the merge of the program. It is going to be nice if a way to evaluate the performance of the new developments out of CFD software (CONVERGE) platform is laid out.

Reviewer 6:
The reviewer commented that the program does not appear to radically stretch use of HPC-based engine modeling to meet future engine design needs with advanced physical models beyond what industry is already applying.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that yes, the project is well-aligned with DOE objectives. All of the development will directly serve the community to better understand and develop advanced combustion systems.

Reviewer 2:
The reviewer commented that yes, techniques only applicable to HPC at the moment can cascade to industry as computing capabilities progress.

Reviewer 3:
The reviewer remarked robust tools to help with engine design and calibration are very much needed to reduce design cycle times and calibration effort and time.

Reviewer 4:
The reviewer said yes, research appears to be targeting DOE objectives of fostering cleaner and more efficient IC engines.

Reviewer 5:
Per the reviewer, virtual calibration is relevant.

Reviewer 6:
The reviewer said this is the type of work that national laboratories should be doing.

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 could be increased to support emissions simulations.

Reviewer 2:
The reviewer stated that for what is proposed, the resources appear to be adequate.

Reviewer 3:
Per the reviewer, it seems that the financial resources are sufficient.

Reviewer 4:
The reviewer found that the resource does seem sufficient.

Reviewer 5:
The reviewer considered the resources sufficient to meet the stated goals.

Reviewer 6:
The reviewer does not believe to be in an adequate position to judge this.

Presentation Number: acs022
Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations [CLEERS] Analysis and Coordination)
Principal Investigator: Josh Pihl (Oak Ridge National Laboratory)

Presenter
Josh Pihl, Oak Ridge 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 and well-planned.

Reviewer 1:
The reviewer found that given the diverse set of modeling tools used by the stakeholder community, the approach of generating appropriate model inputs (kinetics, etc.) for general use is wholly appropriate. The project seems to have two main purposes operating in parallel. First, coordinating CLEERS, and then conducting the related catalytic converter research that CLEERS prioritizes. Per the reviewer, this approach seems to work, though, because feedback from one part feeds the other.

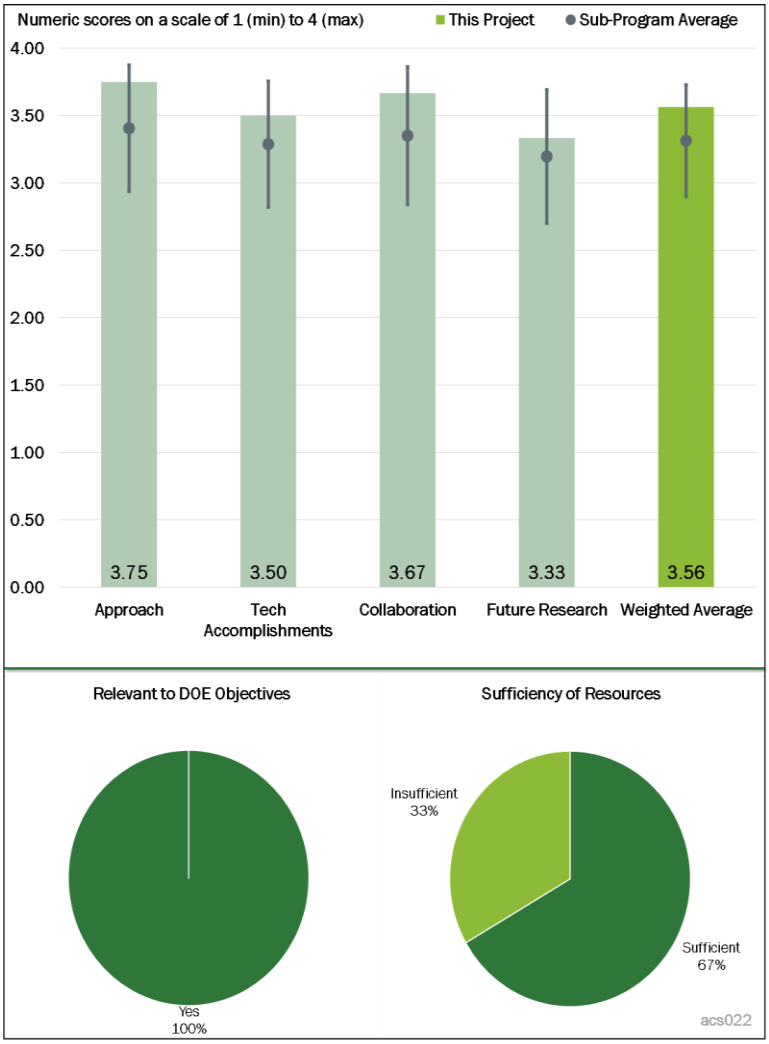

Figure 1-12 - Presentation Number: acs022 Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations [CLEERS] Analysis and Coordination) Principal Investigator: Josh Pihl (Oak Ridge National Laboratory)

Reviewer 2:
The reviewer said that CLEERS utilizes a mix of "tools" such as their website, annual workshop, monthly teleconferences, and expert presentations. Additionally, a flexible inclusive policy, developing strong relationships in dealing with the industry, its issues and challenges, the use of modeling, coordination, and dissemination of relevant information, and so on. The reviewer noted that the CLEERS charter has grown from a mere aftertreatment modeling circle (its initial charter a decade and a half ago) to one now also including engine development topics (gasoline, diesel, natural gas) and testing, and has stayed well connected with industry needs and its outlook.

Reviewer 3:
The reviewer stated the CLEERS annual workshops and monthly focus group teleconferences continue to provide an effective forum for sharing results and ideas related to exhaust aftertreatment modeling. The current

focus on low-temperature oxidation/storage catalysts as well as catalyst aging mechanisms and multi-functional devices is timely and relevant.

Reviewer 4:
The reviewer pointed out that CLEERS directly addresses barriers called out in the 2018 ACEC Roadmap. Meaning that it is still a relevant and important activity for DOE to fund. This cross-cutting group spans industrial, academic, and national laboratory researchers and encourages the interaction between the groups.

Reviewer 5:
The reviewer remarked CLEERS continues to provide much-needed pre-competitive collaboration by emission researchers from a variety of companies and institutions on multiple emission challenges, including SCR, passive NO_x adsorber (PNA), and low-temperature catalysis. It provides this service by planning and coordinating the annual CLEERS conference, monthly teleconferences, and the semi-annual CLEERS survey. It also is performing technical analysis of catalysts to provide the data needed for computer models of such catalysts.

Reviewer 6:
The reviewer described that the Cross-cut Lean Exhaust Emissions Reduction Simulations (CLEERS) organization supports and promotes the research and development of innovative catalyst technologies by hosting multiple venues. In particular, the annual CLEERS workshop and monthly teleconference serve as excellent forums for disseminating information related to advanced aftertreatment materials and technology directions. Also, through the annual aftertreatment survey, focus areas of research are communicated to the catalysis community. However, care should be taken when interpreting the survey to make sure OEM needs are actually addressed.

The reviewer said that with respect to research efforts conducted by the CLEERS group, the shift in research emphasis to PNAs is consistent with the needs of OEMs to address LTAT. The PNA and selective catalytic reduction (SCR) modeling efforts of this group have been very helpful in characterizing and understanding the behavior of these catalysts in vehicle applications. The reviewer suggested, however, realistic test conditions meant to simulate cold start could be better captured in the characterization conditions, as well as proper aging.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that the team has posted on the CLEERS website catalyst test protocols developed by the Low-Temperature Aftertreatment subgroup, and are starting to receive considerable attention from catalyst researchers in academia. Also, the annual CLEERS Workshops continue to attract significant interest, as evidenced by the increasing number of attendees in recent years.

Reviewer 2:
The reviewer said there are several accomplishments of note from the CLEERS activities. First is hosting the annual CLEERS workshop, which is very successful. Second is their contribution to United States Driving Research and Innovation for Vehicle efficiency and Energy (U.S. DRIVE) efforts to develop protocols for characterizing catalysts and accelerating the development of new catalyst materials. Third is their annual survey highlighting catalysis focus areas.

The reviewer pointed out that CLEERS' work in characterizing and developing PNA catalyst materials addressed LTAT needed by OEMs for both lean and stoichiometric exhaust systems. The reviewer commented that progress appears slower than expected and incorporating poisons and proper aging into their test protocols is highly desirable.

Reviewer 3:
The reviewer said that it is still in the early days with the adsorber technologies, but the results seem like they could be promoted more widely, e.g., SAE conferences or publications. The reviewer questioned whether there are more opportunities for joint publications showing how the data from this project are being applied in industry. The reviewer perceived that the CLEERS workshops and other activities are an asset for the broader stakeholder community.

Reviewer 4:
The reviewer detailed how CLEERS is a government sponsored program having created its own benchmark. It has grown from a small circle to one having industry wide impact, even outside the United States. CLEERS monthly teleconferences have become highly educational and stimulating, and its annual workshops have become one of the best interaction opportunities in the "development" circles. The reviewer pointed out that CLEERS' focus has expanded to include discussions on various combustion, emission, and proper topic diversity (relevance). The reviewer congratulated the ORNL project team for having created such a stimulating circle for information exchange.

The reviewer said that while CLEERS did a good job integrating properly modern gasoline engine developments in its focal discussions, it has been slow in directing sufficient focus from lean NO_x trap to SCR to accommodate the HD diesel industry needs and trends. Nevertheless, in the absence of the still-missing Directions in Engine-Efficiency and Emissions Research (DEER) conference, the value of CLEERS is growing fast. Its absence from the powertrain community would create a major interaction void much needed in today's quickly changing powertrain atmosphere.

Reviewer 5:
The reviewer noted that the annual workshop and the monthly teleconferences are always well done and well attended. The industry survey is of benefit to lab and university researchers to continue to pursue high priority work. The reviewer noted on the technical results presented in Slides 17-22, because the changes are so small, the reviewer suggested that it would have been really nice to have some idea of the error associated with the measurements. In order to understand how significant the differences are, the reviewer suggested error bars on the bar graphs.

Reviewer 6:
The reviewer said this was a very interesting parametric study on the PNA technology, including the effects of water (H_2O), CO_2, nitric oxide (NO) level, and O_2 level. The reviewer would have liked seeing the effect of S level on the PNA performance as well as the effects of temperature and air/fuel (A/F) ratio during aging. On the effects of O_2, it would have been interesting to look at 0% O_2, to represent stoichiometric operation. For H_2O, the reviewer would have liked to see the range extended down to zero, to see how much the total absence of H_2O improves the oxides of nitrogen (NO_x) storage performance. The reviewer suggested looking at the effect of different hydrocarbons and H_2 on the performance as well.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer pointed out there is excellent collaboration between ORNL, PNNL, the ACEC Technical Team of USCAR, the cross-cut team, universities, etc. The reviewer commented that this project is the poster child for collaborative research.

Reviewer 2:
The reviewer said CLEERS has done an outstanding job in helping develop proper collaborations with the industry, academia and national laboratories. It has indeed gone above and beyond its initial charter, brought "added value" to the industry, and has made a positive, irreversible impact. The project is a model for wide-ranging interactions across various sectors (emissions, engine, light, heavy, etc.).

Reviewer 3:
The reviewer remarked the CLEERS organization has very good collaborative and partnership programs across OEMs, suppliers, universities, and other national laboratories.

Reviewer 4:
The reviewer said the larger groups (ACEC Technical Team, and CLEERS Workshop participants) provide breadth and depth of collaboration. The collaborators do appear to inform the research directions taken.

Reviewer 5:
The reviewer said that the coordination of OEMS, national laboratories, universities, and suppliers is clearly a strength of this activity.

Reviewer 6:
The reviewer noted good and effective collaboration between engine/vehicle manufacturers, universities, and national laboratories. However, the reviewer would like to see more active interaction and engagement with catalyst suppliers.

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 in general, the project's work continues to support the movement toward high fuel efficiency engines by modeling and characterizing catalyst technologies that enable these engines. In particular, focusing on PNA and SCR technologies that are able to function at low temperatures is extremely important for meeting Tier III emissions standards. The reviewer said that staying closely connected with OEMs and their supplier base will help direct the projects towards appropriate technologies.

Reviewer 2:
The reviewer remarked this project ends in FY 2018, but seems likely to continue. Because the current project seems to have two parts operating in parallel (CLEERS coordination and CLEERS research), the reviewer suggested that perhaps it would be worth considering splitting the two parts into separate projects.

Reviewer 3:
The reviewer remarked CLEERS' research work in aftertreatment has stayed in synch with industry activities, although some other key industry challenges have not been regarded. Examples the reviewer cited include high failure (warranty) rate in HDD emission control components/systems, or algorithm development for urea injection, an area of considerable importance especially with growth in SCR focus as a primary means of NO_x reduction. Having said this, the reviewer also understood that their resources are not infinite as the team may not be able to target all existing needs.

Reviewer 4:
The reviewer commented that this is such a worthy activity because there is an on-going need for coordination and collaboration, especially as we tackle the upcoming problems of gasoline particulate filters (GPF), and low-temperature (LT) aftertreatment.

Reviewer 5:
The reviewer noted that the durability studies on PNAs and hydrocarbon (HC) traps are much needed, including the effects of aging temperature and A/F ratio. The effects of S will be a ripe area for study as well, as well as the ability to desulfate the catalyst.

Reviewer 6:
Per the reviewer, there is perhaps too much focus on aftertreatment technologies (e.g., SCR) for diesel and other lean-burn engines. The reviewer suggested that it might be appropriate to look beyond conventional ICE's, such as hybrids, which may play an important role during the transition to all-electric powertrains.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked, in general, this project team's research efforts are strongly coupled to the desire of OEMs to meet future emissions requirements by employing LT aftertreatment systems. The Also, CLEERS activities are strong, encouraged, and supported.

Reviewer 2:
The reviewer commented CLEERS and the research activities it helps coordinate are supporting DOE objectives for more efficient ICEs. Higher engine efficiency generally means lower exhaust temperatures and a corresponding challenge in emissions control.

Reviewer 3:
The reviewer pointed out this project well supports the overall DOE objectives by focusing on efficient ways to reduce exhaust emissions while at the same time improving fuel efficiency.

Reviewer 4:
The reviewer commented that this project absolutely supports the overall DOE objectives. This is one of the core and key activities of the VTO emissions portfolio.

Reviewer 5:
The reviewer noted the catalysts that are being investigated (PNA, HCT, SCR, LT catalysts, etc.) will be necessary to meet stringent emission standards with the advanced combustion concepts that are being investigated to improve fuel economy. So, all the work supports the DOE objective of reduced fuel consumption.

Reviewer 6:
The reviewer said yes, and by a large margin.

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 every year, under the CLEERS umbrella, ORNL (and to some extent PNNL) do a lot of work in coordinating the workshop, teleconferences, newsletters, and surveys. In addition, the team brilliantly leverages the CLEERS funding and insight to advance the knowledge base in specific catalyst areas. In fact, it is common to see previous reviewer questions such as "why aren't you studying XYZ catalyst?" as there are not currently enough resources for ORNL to be actively working in all of the industrially relevant research areas as identified by industry itself in the survey. The reviewer commented that based on the amazing work the team pulls off, the reviewer can only imagine what more they could do with additional funding.

Reviewer 2:
The reviewer found it difficult, as an ORNL outsider, to judge how wide CLEERS' resources are. The reviewer commented that because some of the niche industry needs remain untackled, it is fair to say the team could benefit from more resources.

Reviewer 3:
To this reviewer, it appears that the current levels of resources are sufficient. If similar work expands into the area of HC traps while maintaining the work on PNAs, there might be a need to expand the level of resources.

Reviewer 4:
The reviewer commented that the resources appear to be sufficient. However, funding should be set before the current FY to ensure projects are not delayed.

Reviewer 5:
The reviewer commented this project involves both coordination and support/execution of emission control research. However, it appears that the coordination effort takes up considerable amounts of resources, leaving insufficient resources available for the other part.

Reviewer 6:
The reviewer stated that the resources available seem well-matched to the project objectives.

Presentation Number: acs023
Presentation Title: CLEERS: Aftertreatment Modeling and Analysis
Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Presenter
Yong Wang, Pacific Northwest National Laboratory

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 and well-planned.

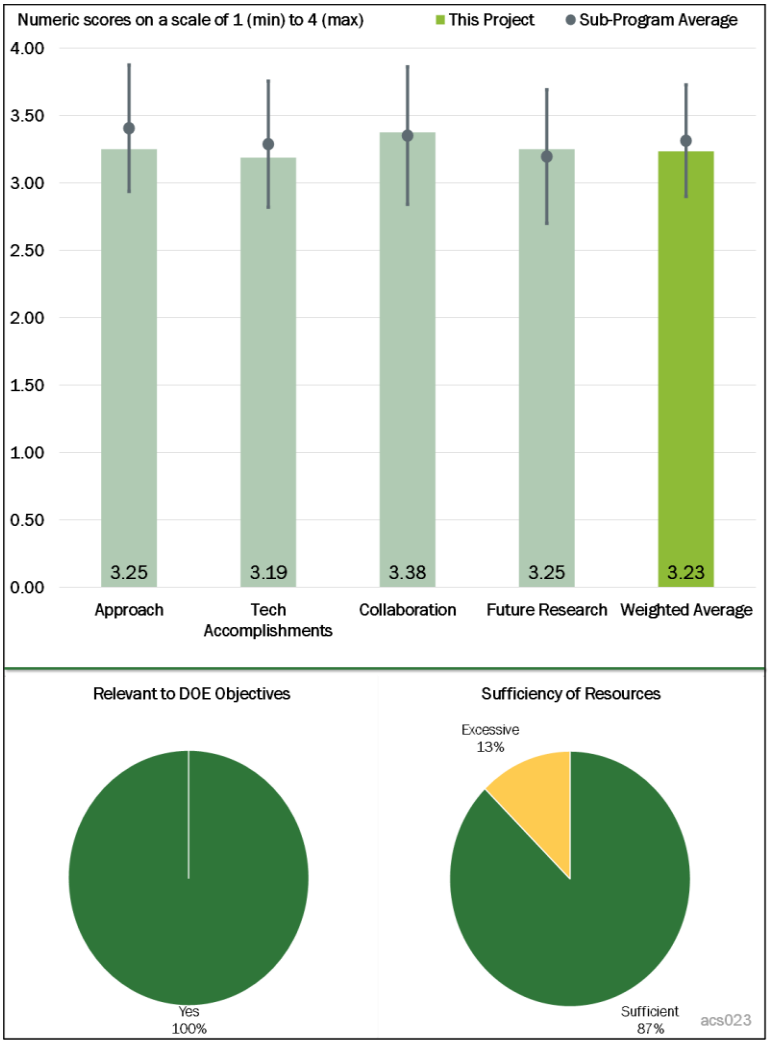

Figure 1-13 - Presentation Number: acs023 Presentation Title: CLEERS: Aftertreatment Modeling and Analysis Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Reviewer 1:
The reviewer said that the range of activities of PNNL's CLEERS work, combined with that of ORNL, makes for a very strong effort to look at areas that have been cited for interest in the survey of industry, a major piece of learning that comes from the survey. A yearly survey could be useful, but the surveyed might not like it. It would be worth finding out. The reviewer noted that part of the approach is also the development of protocols for doing experiments in important areas like storage materials or oxidation catalysts. These are done in interaction with the ACEC group of DOE. These experimental protocols to follow are developed by active practitioners to make it easier, as one goal, for new researchers in that area (e.g., from a university) to achieve results and develop new catalysts that will be relevant and tested sufficiently to be of interest, ultimately, to the companies and laboratories that are using these catalysts. The reviewer said that very visible, but also very important, is the arrangement of approximately monthly presentations to the CLEERS members and collaborators in this project of recent work via a teleconference presentation.

Reviewer 2:
The reviewer commented the PNNL team is focused on fundamentals of several key emission control technologies; SCR, PNA, selective catalytic reduction on filter (SCRF), and LT oxidation. The reviewer pointed out strides are being made in moving SCR activity to lower temperature. This melds nicely with the work on PNA, although, the reviewer was unclear from the project review as to which of the two is more important in meeting the 150° Celsius challenge.

Reviewer 3:
The reviewer stated that this project demonstrates the excellent application of PNNL's expertise in science to study real-world emission problems.

Reviewer 4:
The reviewer commented this program addresses a broad range of technical barriers across multiple technologies. The LTAT catalyst formulation work seems promising if it can be made commercially viable. The reviewer commented that on Slide 9, the legend is missing, and the heat treatment conditions are unclear.

Reviewer 5:
The reviewer said the project has sharpened its focus and resources to tackle the emerging catalytic material challenges from a fundamental perspective in SCR, PNA, and LTAT. The research work pertaining to material characterizations and rational optimizations were particularly thought out, and an extensive collaboration with both academia and industry sees positive outcome. Despite the solid content, the reviewer said that the actual work does not truly echo the project tile of "modeling" from a reaction-engineering point of view.

Reviewer 6:
The reviewer remarked the strategy is appropriate, but the range of partners appears to be somewhat limited and could result in the project being too specifically focused on the commercial needs of one coater/one OEM.

Reviewer 7:
The reviewer noted that CLEERS, by its very name, is simulations focused. The reviewer commented that it is not clear how these PNNL projects support that mission anymore. Over the past several years, we have seen the approach of this project drift away from usefulness. The reviewer said it is clear that ORNL takes the lead on coordination of the website, workshop, and monthly calls. In particular, the reviewer is bothered by the statement on Slide 5 to "utilize CLEERS work to support industry cooperative research and development agreement (CRADA) activities"—which should be supported by their own funds, not CLEERS. It also completely disagrees with the following bullet to "maintain clear separation between CLEERS and CRADA activities."

Reviewer 8:
The reviewer commented that the project is spread too thin. It would be better to stick to two or three topics maximum as opposed to the four chosen here. Also, per the reviewer there should be more emphasis on modeling than was presented here.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that the technical accomplishments have been excellent. The fundamental understanding gained on SCR (such as electron paramagnetic resonance [EPR] work, alkali addition), PNA, and oxidation (single atom catalysis) has had different impacts. With SCR, the work supports the emerging consensus about copper/chabazite (Cu/CHA); one does wonder if continued work on SCR is justified given that urea is still limited to 180°C minimum operation. The reviewer remarked industry has avoided the ammonia (NH_3) generating solid materials. With PNA, the impact is on understanding the underlying mechanism necessary for modeling. The reviewer pointed out the synergy here with ORNL is critical. With oxidation, the demonstration of LT activity due to high-temperature treatment has potentially very important implications for emission control in general.

Reviewer 2:
The reviewer commented that the technical accomplishments have been met with a large measure of published work (14 papers) with results that are very significant in that area of SCR catalysts and PNA materials in particular, areas of great interest to companies in this field. The reviewer stated that accomplishments are well-

described in the presentation. Other accomplishments also include the protocols developed through interaction with the ACEC group.

Reviewer 3:

The reviewer said it has been claimed that the LT SCR activity was increased with co-cation addition. The reviewer does not think the improvement is significant when compared, for example, with the high-temperature durability. The experiments need to be done at varying space velocities to discern effects of improved kinetics versus improved pore diffusion. The reviewer said that for PNA, it will be useful to develop a mechanism and validate with reactor experiments. For computerized tomography (CT) work, this type of work has been done. The reviewer said the value will be to demonstrate using the wall-scale coating distribution to predict filter-scale performance (pressure drop, filtration, etc.). Even if directionally correct, that will be a big step forward.

Reviewer 4:

The reviewer said that if the PNA and 150°C milestones are met, the program appears to be on schedule. The reviewer commented that there is good alignment between the individual projects and the stated barriers. For instance, the LT performance barrier is addressed in LTAT and SCR work, while the PNA work is focused on underlying mechanisms. The generation of 14 peer reviewed papers as well as the LT test protocol work is impressive.

Reviewer 5:

The reviewer gave kudos to the project team for performing the work writing up the catalyst testing protocols. The reviewer found that identifying different copper species with different hydrothermal aging (HTA) conditions very interesting. Because the project is attempting to improve the LT activity of the SCR catalyst, it would have been nice to have looked at the effects of S poisoning on the co-cation formulations, because S tends to decrease the LT activity of SCR catalysts. The reviewer found the analysis of the PNA technology was excellent. The reviewer questioned whether the effect of CO on the NO_x storage could be consistent with the formation of nitric oxide and carbon monoxide, because 2150 cm^1 corresponds to isocyanate. Very interesting work on the single-atom Pt catalyst. The reviewer commended the project team for looking at the effect of S on its performance.

Reviewer 6:

The reviewer commented that while the quality of analysis is good e.g. for the nature of the Cu species in Cu-CHA, and the interpretation sound, the work does not appear novel. For example, Slide 7 highlights findings known within the field of SCR for several years. In addition, the use of co-cations in Slide 8 is more of an academic artifact. The reviewer said that using co-exchanged Cu and alkali metals would be challenging on a commercial scale, and the project team does not address potential issues arising from high-temperature mobility of alkalis such as solid state reaction and subsequent degradation of cordierite. The PNA characterization and analysis was well-conceived and executed with a solid interpretation.

The reviewer said that the analysis of SCR filter shows coating of an asymmetric cell diesel particulate filter (DPF) and dictates massive maldistribution of washcoat. The reviewer questioned whether this was a commercial SCRF. The reviewer has never seen such an issue on a commercial product. This would result in significant flow by-pass and loss in performance, which the reviewer does not think has been reported in the field. The reviewer remarked the platinum (Pt) 1/cerium oxide (CeO_2) catalyst is an academic artifact. The cost to produce this reproducibly on a commercial scale would likely be prohibitive. In addition, the test protocol does not include any of the known transient poisons, such as heavy hydrocarbons that would delay light-off. It gets headlines but actually detracts from the real challenges in emissions control.

Reviewer 7:

The reviewer remarked the project has made significant progress that largely exceeds the committed expectation from last year's report. The relevance of the fundamental findings in addressing practical

challenges is highly visible. However, the reviewer emphasized that the 150°C challenges are far from being solved in terms of both absolute activity (not just showing temperature but absolute turnover rate) and durability, particularly for prevalent gasoline LD vehicle adoptions in the United States.

Reviewer 8:
The reviewer commented that it is nice to see publications resulting from this work, but they seem to be at a fundamental level, below the useful level for supporting device level models, which is the focus of CLEERS. The reviewer was surprised to see the LT protocols called out as accomplishments under PNNL's part of CLEERS as this was a joint effort. The reviewer would like to echo another reviewer's comment from last year that it would be nice to understand what part of this work was used successfully by companies in models, in line with the mission of CLEERS.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented this is a role model that other projects should be measured against.

Reviewer 2:
The reviewer said the range of collaboration and coordination on this project encompasses the entire commercial, national laboratory, and university community doing research and using results in this area.

Reviewer 3:
The reviewer stated there was great collaboration between PNNL and the ACEC Technical Team for developing the catalyst protocols. Collaboration in the areas of SCRs and PNAs was not as obvious.

Reviewer 4:
The reviewer suggested that PNNL needs to more clearly synergize with the ORNL CLEERS project. In particular, PNA is common to both project teams, but it is unclear how the work of both teams will lead to a PNA model. Along these lines, the PNNL team's focus on the fundamentals is laudable. The reviewer said, however, there does not seem to be any effort to develop predictive models. This, after all, is the main objective of CLEERS.

Reviewer 5:
The reviewer suggested that it will be useful to get a catalyzer on-board the team or get their technical inputs.

Reviewer 6:
The reviewer said the team shows a good range of partners, although these are primarily in the academic sector.

Reviewer 7:
The reviewer commented a few of collaborations that exist with CRADA partners seem strong. The reviewer questioned how much PNNL really collaborates with ORNL on coordination of CLEERS as it seems to be solely ORNL.

Reviewer 8:
The reviewer remarked this program seems to create future collaborative efforts (CRADA). The reviewer found the level of collaboration and coordination on the individual projects difficult to judge due to a lack of sufficient information in the presentation slide deck.

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 the proposed future work is extensive and guided by the excellent accomplishments thus far. Especially interesting would be the future results to understand the distribution of SCR catalyst material in SCR-filter multi-functional devices. This is especially true, because of the great interest in making more compact systems that still maintain excellent functionality in the exhaust. The reviewer said results here could guide work on both SCR catalysts and filters to make them more capable in this area.

Reviewer 2:
The reviewer stated that the proposed future work follows on logically from current undertakings.

Reviewer 3:
The reviewer commented that the overall proposed future research direction is good, but there should be greater emphasis on coming up with product level models which are validated with transient experiments.

Reviewer 4:
The reviewer remarked the team intends to address a range of challenges pertinent to the industry. The reviewer would recommend including an increased range of industrial partners.

Reviewer 5:
The reviewer suggested that the project team investigate the effect of S on the low-temperature activity of the new SCR catalyst. It would also be interesting to examine the effects of other exhaust species on the performance of the Pd/SSZ-13 PNA catalyst, including hydrocarbons, H_2, CO_2, H_2O, and sulfur dioxide.

Reviewer 6:
The reviewer said that stability of the PNA under DPF regeneration rich spikes has been identified as a major roadblock for the potential application of PNA in the United States. The reviewer suggested that the corresponding anti-deactivation mechanism and approach should be studied with considerable urgency.

Palladium (Pd) and alumina are the workhorse of the low-temperature oxidation catalyst formulation that this project has not addressed. The reviewer said the cross comparison of temperature at which 50% conversion occurs (T50)/temperature at which 90% conversion (T90) (not the absolute activity) in current report slides is not sufficient to exclude other formulations other than the simple Pt/CeO_2, the latter of which is clearly not active for propene (C_3H_6) conversion despite the satisfying CO oxidation activity. The reviewer remarked a continued optimization of formulation and structure is more anticipated before conducting application-oriented durability studies.

Reviewer 7:
The reviewer commented that the focus on fast SCR is questionable, and asked what is to be learned. Standard SCR is slower than "fast" SCR, so it is not clear what the goal is. Moreover, with fast SCR a $NO:NO_2 = 1$ ratio is needed. The reviewer asked from where the NO_2 comes from at temperatures of less than 180°C.

Reviewer 8:
The reviewer said one of the reasons that the future work was not rated higher is because the reviewer lacked confidence that the project team will listen to reviewer comments.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said increasing the efficiency of IC engines is a technologically proven and cost-effective approach to dramatically improving the fuel economy of the nation's fleet of vehicles in the near- to mid-term. This is an overall result of this project, providing its relevance to DOE objectives.

Reviewer 2:
The reviewer commented that yes, it does support overall DOE objectives, as development of models and reaction mechanism will help towards improved catalysts and LT performance.

Reviewer 3:
The reviewer said the work has a sound basis, it has realized some significant milestones towards to DOE goals. There is evidence of significant and meaningful collaborations and some examples of commercially relevant developments.

Reviewer 4:
The reviewer said the project has sharpened its focus and resources to tackle the emerging catalytic material challenges that U.S. vehicle technology needs. The reviewer appreciated the very positive response to last year's reviewer comments.

Reviewer 5:
The reviewer remarked the catalyst technologies the project is investigating are necessary to allow the implementation of advanced engines and combustion concepts that are being developed for reduced fuel consumption while simultaneously meeting strict emission standards.

Reviewer 6:
The reviewer found the topics of inquiry are generally in line with DOE interests.

Reviewer 7:
The reviewer stated that the program is well-aligned with the U.S. DRIVE ACEC Roadmap.

Reviewer 8:
Per the reviewer, this project has obvious relevance to DOE objectives.

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 PNNL has excellent facilities to conduct the research.

Reviewer 2:
The reviewer remarked the team is addressing several challenges but are well-funded. Thus, any issue in delivery is not for want of support.

Reviewer 3:
The reviewer commented that the projects appear sufficiently funded.

Reviewer 4:
The reviewer said based on the quality of the results and the large number of collaborators who support this project, its resources appear to be sufficient to the task.

Reviewer 5:
The reviewer stated that it appears the resources are sufficient for this work.

Reviewer 6:
If resources are scarce, the reviewer suggested that the project team focus on fewer areas than the four currently chosen.

Reviewer 7:
The reviewer commented the team has already secured enough resources to achieve the committed goals. The reviewer expected to have a clearer description from the project team regarding how the knowledge generated from this project teaches industry breakthroughs. This is a vague point in current state of the work, and it is hard to justify if the industry resources have been utilized.

Reviewer 8:
The reviewer recommended consolidating the CLEERS program under ORNL and letting PNNL focus solely on their CRADA projects, which seems to be what happens with their CLEERS budget too.

Presentation Number: acs027
Presentation Title: Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation
Principal Investigator: Abhijeet Karkamkar (Pacific Northwest National Laboratory)

Presenter
Abhijeet Karkamkar, Pacific Northwest 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 and well-planned.

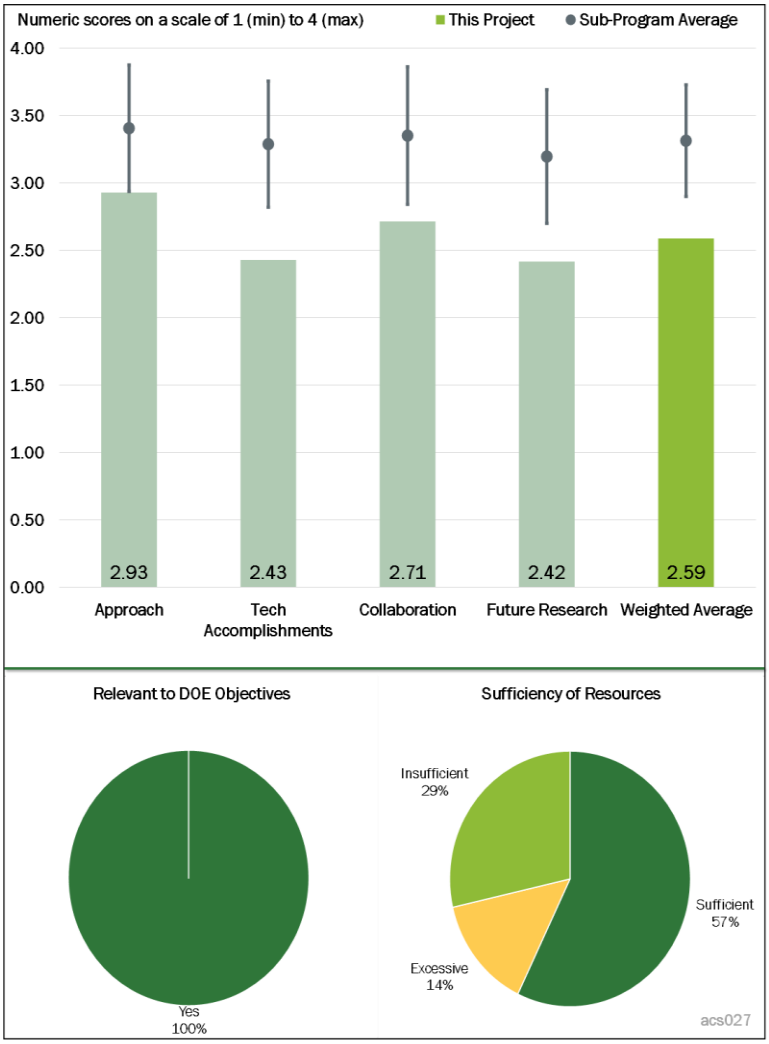

Figure 1-14 - Presentation Number: acs027 Presentation Title: Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation Principal Investigator: Abhijeet Karkamkar (Pacific Northwest National Laboratory)

Reviewer 1:
The reviewer pointed out that because of reviewers' comments in 2017, the goal of the project was made to include materials for NH_3 storage that do not include chlorine (Cl), especially because Cl had been observed as present in the outflow from the solid storage material. A choice was made to look at oxide materials, which would be one way to go. Because there were already materials, like ammonium carbamate, in the list of candidates that did not include Cl, this reviewer would have preferred a shift to understanding the barriers perceived for that material or other non-Cl materials on the list. Although unstated here, the perceived issue there appears to be the reported reformation of ammonium carbamate in cooler areas of a tube or a valve after it is put in the gas phase. Hence, an approach to define the temperatures, concentration/dilution dependence, and "sites" necessary for that reformation would seem to be of importance to see if it could be minimized. The reviewer said that potentially the energy cost of selective removal of CO_2 from the outlet gas from the heated section could be explored (and may have been, based on Slide 14, although not mentioned in summary of results). Such a change in the approach would shift the skill sets included in the project, but these are certainly achievable with the laboratory personnel present.

Reviewer 2:
The reviewer commented the project seeks to identify a suitable replacement to aqueous urea for lower temperature, compact generation of NH_3. This past year the team has focused on finding non-chloride compounds because hydrochloric acid (HCl) generation is to be avoided. That said, as presented it seemed to the reviewer as though there was too much sustained consideration of Cl-containing compounds and not enough consideration of weakly acidic metal oxides. The latter is the target, but per the reviewer the project

does not appear to have a systematic as opposed to Edisonian approach. The project would benefit by classifying a class of compounds in terms of their acidity and perhaps include a high throughput screening approach in place to accelerate discovery.

Reviewer 3:

The reviewer commented that the approach is good, but more rapid screening should be undertaken to address the constraint of finding a new non-chloride based material.

Reviewer 4:

The reviewer said that this appears to be a viable downselection process for an alternative NH_3 storage medium for SCR. There is some question of the commercial viability or industry acceptance of transitioning to a new NH_3 storage medium given the pre-existing urea water solution/liquid urea (DEF) infrastructure. Some clarification or comment on the commercial viability would have been very helpful. The reviewer found Slides 15-18 difficult to follow. Additional information such as a legend or description is needed.

Reviewer 5:

This project tackles the practical limitations of NH_3 storage (controlled storage plus volume change) in current urea-based SCR systems for the low-temperature diesel NO_x emission control. The team considered last year's recommendation for the latest work to investigate the impact of Cl release and to search for more material candidates.

Reviewer 6:

The reviewer pointed out that a non-urea source of NH_3 will be necessary to allow NO_x conversion below 180°C, because this is the temperature at which urea decomposes to NH_3. So this project is needed to explore various non-urea sources of NH_3. The reviewer found it commendable that the author listened to feedback and made efforts to minimize Cl emissions, in order to avoid HCl in the exhaust which can cause corrosion problems.

Reviewer 7:

The reviewer said while there were clear statements regarding the challenges related to the current use of DEF and the nature of some of the targets required for replacement of DEF by a solid system, the team did not provide sufficient detail regarding how the solid system would or could be implemented. The reviewer remarked the presentation gave the impression that the project was highly exploratory and academic in nature and had limited connection to real end-users such as washcoater, OEM, and system integrator. Given the advanced state of the project, the reviewer was surprised not to see any demonstration data on an engine dynamometer or a vehicle.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pointed out that as for progress, the current benefits in chemistry seems to be incremental rather than revolutionary compared with the baseline technology. The project identified several indications of the promising role about the eutectic salts. However, further confirmation and optimization is still under way. The reviewer found the quantified conclusions to be limited.

Reviewer 2:

The reviewer remarked the data presented were of reasonable quality, but was solely laboratory-based and described only model systems. Moreover, in Slide 11, for the comparison of HCl measurements, there was no standard test protocol, which makes comparison of some of the data points challenging. In addition, the temperatures quoted are all significantly higher than the lower temperature challenge window of "urban

driving" shown in Slide 22. The reviewer pointed out that in Slide 14, the project team share data on the CO_2 adsorption, another model system. The reviewer questioned why not NH_3 because this is the aim of the project. In Slides 15-18, the team share thermogravimetry/differential scanning calorimetry data for NH_3 loss from another model system. However, this is a one-shot test; the reviewer asked did the team execute repeat cycles of uptake and release or does the team envision the system a one-shot use cartridge versus a rechargeable unit. If the latter, this "disposable" solution would make it a less attractive alternative to DEF.

Reviewer 3:
The reviewer noted that the team has generated some interesting data, but it does not appear the team has selected a final candidate for the storage medium. The reviewer commented that this is the fourth year of this study and the results do not seem to point in a clear direction relative to the goal of the project.

Reviewer 4:
The reviewer said the studies of eutectic and oxide materials provided new information on those as solid NH_3 storage agents. None appeared able to compete effectively with compounds on the existing list. Slide 14 considers CO_2 storage, but appears alone on that topic. The reviewer said that data slides, in general, did not include a take-away message that connected them to other work. The reviewer suggested that, although this project is ending soon, it would be good to pull these results together.

Reviewer 5:
The reviewer remarked progress towards identifying attractive alternatives appears to have stalled. In part this is a result of avoiding metal halides. The project may benefit from bringing in a materials chemistry expert who is versed in molecular computational methods.

Reviewer 6:
The reviewer stated that the progress is rather limited. The project seems to be still far away from identifying a new material which comes close to the desired properties.

Reviewer 7:
The reviewer found it difficult to understand the plots which showed weight loss versus temperature. The reviewer questioned how this shows NH_3 uptake and release. Perhaps the figures need to be explained in more detail in future presentations so the audience can better understand them. The reviewer also found that more explanation of the test procedures would be helpful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the collaboration with the USCAR SCR team is most appropriate. Possibly an even broader set of contacts could be employed to get a broader view of the options for this project to consider and follow through on.

Reviewer 2:
The reviewer said that the project has obvious collaboration between USCAR and PNNL. The reviewer stated that PNNL is very responsive to suggestions from USCAR member companies.

Reviewer 3:
The reviewer considered the coordination between PNNL and USCAR adequate.

Reviewer 4:
The reviewer suggested that it may be useful to involve industry to a greater extent to expedite the discovery and testing of new materials as some may already have been explored earlier.

Reviewer 5:
The reviewer stated that the project claimed frequent communications with the USCAR organization and OEM development teams. However, the technical guidance and commitment from the OEM side seems insufficient. The reviewer noted that limited evidence in the report to show obvious engineering and control support from OEMs.

Reviewer 6:
Per the reviewer, there was limited evidence of collaboration demonstrated in either the slides or shared verbally.

Reviewer 7:
The reviewer expressed not seeing much evidence of collaborations with other researchers or other institutions.

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 future plans were to continue looking at oxide materials, mentioned on Slide 9. A novel concept for NH_3 adsorption was mentioned on Slide 9, but no results or explanation was given, especially for future research. The reviewer found that there was no actual slide on future plans. The reviewer said that if USCAR continues this project, the comments made on changes in approach would hopefully be considered. Because there was an overlap in the scheduling of the AMR meeting and the meeting of the North American Catalysis Society (NAM 25) in 2017, the reviewer was unable to participate at AMR.

Reviewer 2:
The reviewer commented that the project management seems, in comparison to other projects, somewhat disorganized. The project has laudable objectives, but it seems like a more systematic approach could be taken. For example, molecular-level computations might be a way to accelerate the discovery of new materials.

Reviewer 3:
The reviewer suggested considering non-chloride salts.

Reviewer 4:
The reviewer said no future work has been outlined, probably because the project ends in September.

Reviewer 5:
The reviewer remarked a verbal statement was made in this regard, but only a limited view was shared in the slide deck.

Reviewer 6:
The reviewer said current work appears to continue until project end in September. The reviewer found that no future plans beyond this are apparent.

Reviewer 7:
The reviewer said the project is about 3 months away from completion and it is hard to gain the confidence that an alternative NH_3 carrier material can be sufficiently developed and become ready for SCR dosing study on a system level in that time.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer pointed out that a low-temperature SCR activity is key to improving de-NO_x performance, and such basic research on the topic is important.

Reviewer 2:
The reviewer stated that low-temperature NH_3 dosing for SCR supports fuel-efficiency and emission regulation goals for diesel engines.

Reviewer 3:
The reviewer remarked engines with higher fuel economy will produce lower exhaust temperatures, which will require catalysts that can treat the emissions at those lower temperatures. If SCR catalysts are developed that can provide NO_x conversion at 150°C on diesel engines, there will be a need for NH_3 delivery systems that can provide NH_3 at 150°C without forming deposits on the catalyst. Thus, per the reviewer this project supports DOE's goal of reduced fuel consumption.

Reviewer 4:
The reviewer said volume-efficient storage and fast release of the stored NH_3 when needed are critically important for fully utilizing the catalytic capability of any given SCR catalysts downstream.

Reviewer 5:
The reviewer stated that a replacement for urea as NH_3 source is critical to reduce the low-temperature hurdle for SCR.

Reviewer 6:
The reviewer said the work is a limited attempt to address a known issue in the field of emissions control. However, the character is highly academic in nature and there is limited substance or end-user specific examples shared by the team.

Reviewer 7:
The reviewer commented clearly, a successful discovery of a material and its usability for solid NH_3 storage would improve fuel economy by using a temperature range where SCR catalysts function, but the NH_3 reductant is not able to be used now because of urea's relatively high decomposition temperature.

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 resources at PNNL are sufficient for this project. The reviewer found that any resources provided by the U.S. DRIVE SCR team were unclear.

Reviewer 2:
The reviewer stated that the resources for this project appear to be sufficient.

Reviewer 3:
The reviewer said the project utilizes capabilities and facilities at PNNL. However, it seemed as if these could be used even more comprehensively.

Reviewer 4:
The reviewer stated given the limited progress made on the topic and considering the ambitious goal, it may be useful to add some more collaborators from industry and expedite the screening process.

Reviewer 5:
The reviewer said given the limited scope of activities, the level of funding appears appropriate.

Reviewer 6:
The reviewer commented the project essentially remains at the stage of preliminary ideal material screening with qualitative comparisons. A systematic level of resources leveraging does not seem to be necessary to achieve the claimed goals.

Reviewer 7:
The reviewer found that progress seems to be relatively slow, and more resources may be necessary to accelerate the development of these non-urea sources of NH_3.

Presentation Number: acs032
Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NO_x Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems
Principal Investigator: Bill Partridge (Oak Ridge National Laboratory)

Presenter
Bill Partridge, Oak Ridge 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 and well-planned.

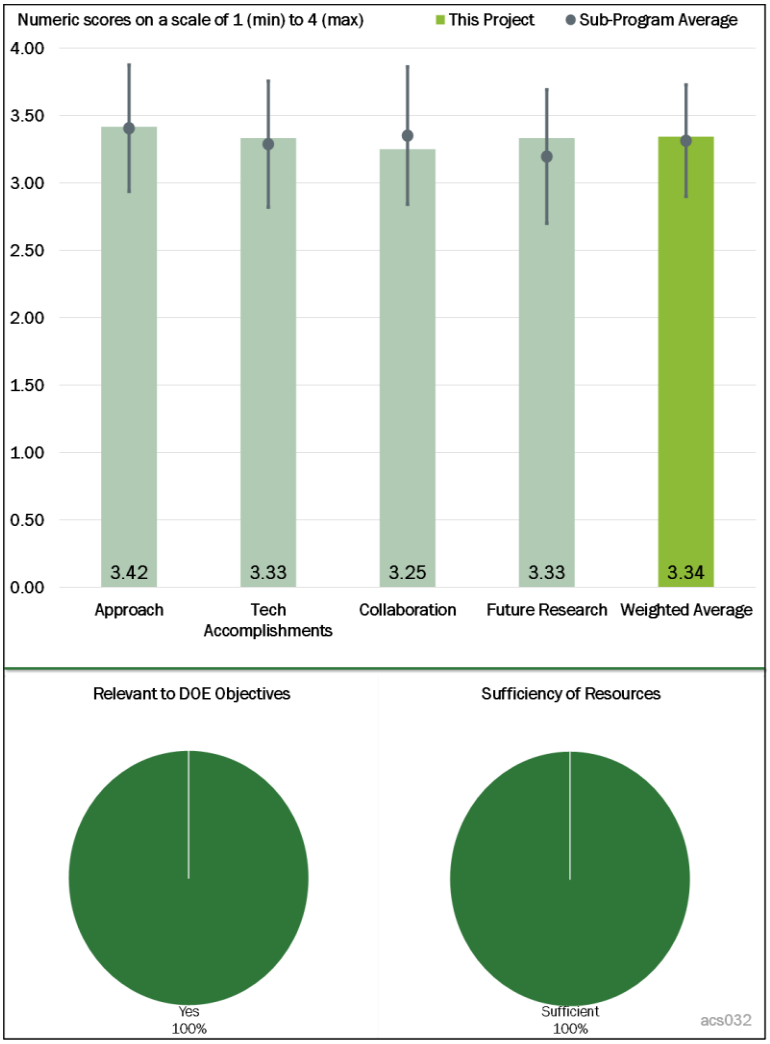

Figure 1-15 - Presentation Number: acs032 Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NO_x Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems Principal Investigator: Bill Partridge (Oak Ridge National Laboratory)

Reviewer 1:
The reviewer said this CRADA has produced some very great instrumental developments. A conversion inflection is a second order effect and as such is more difficult to measure. However, this work has shown a great level of consistency and seems to be able to predict catalyst trends. The inflection trends for light-off curves have been observed for some time. However, this work shows a consistency that give confidence to its predictions. The reviewer found the mechanistic prediction interesting and it appears to be a reasonable explanation of the phenomenon.

Reviewer 2:
The reviewer pointed out that finding novel, cost effective approaches to meet on-board diagnostics (OBD) requirements is of considerable interest to OEMs. This method, using a conversion inflection to diagnose the aged state of an SCR catalyst, falls into that category. The reviewer noted that determining the best way to use a NO_x sensor to obtain this information may be challenging in exhaust conditions.

Reviewer 3:
The reviewer found this to be a novel topic and insightful. This is a relatively novel area of modeling Cu state in SCR of NO_x. The reviewer observed a well-defined project and well thought out. The reviewer commented that the project relies well on published literature and on its approach in relating conversion inflection to the state of Cu.

Reviewer 4:
The reviewer remarked the project has a good balance of modeling and experimental work in parallel.

Reviewer 5:
The reviewer noted the idea of using transient measurements for the development of more accurate SCR models is novel because transient experiments tend to reveal more information about the reaction pathways and mechanisms involved than steady-state experiments. It is clear that the nature and trend of the conversion inflection (CI) phenomenon are correctly captured by the model, but the model validation by direct (side-by-side) comparison of the model predictions and experimental data obtained under the same condition seems to be difficult to find from the presentation (e.g., Slides 21 and 22). Also, the real test would be to integrate the kinetic model developed here with a catalyst thermal model and see how well the model predictions compare with NO_x conversion vs time measured during vehicle emission tests. The reviewer questioned whether this is part of the future plans.

Reviewer 6:
The reviewer said that using SCR Cu-redox approach to formulate SCR reaction with help of a number of very well-defined transient steps is a technically sound approach to understand CI behavior without going into too detailed micro-kinetics. However, it is not clear how significant it is with this CI behavior understanding practically, because this only happens in a very limited condition, even though there may have some academic value there. The reviewer was not convinced if this CI behavior has anything to do with OBD, where authors believe that this would be the case otherwise.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said what was especially impressive is the project team's ability to develop a simple global explanation for the phenomenon. The intuitively simple connection to the copper oxidation state confirms previous speculation. However, this work translates that speculation into a mathematical model. What the project team calls the half-cycle imbalance, to the reviewer is the gradual shift in consumption of the reactants. Or said another way, it is the gradual shift in a reactive steady state point. It also allows the tracking of the copper oxidation state, which is important in most of the other oxidation-reduction reactions.

Reviewer 2:
The reviewer found this to be nice work to probe the two half-cycles in the copper redox reactions separately to elucidate a mechanism for the conversion inflections, especially because the model appropriately describes transient behavior.

Reviewer 3:
The reviewer said the findings are interesting and can be used in better understanding Cu state in SCR of NO_x. Displaying "fast SCR" reactions at such high temperatures (400°-500° C) is impractical. Equimolar NO-NO_2 is simply not available at those temperatures in SCR of NO_x in diesel emission control. The reviewer said this is not meant to question the CI analysis fundamentals or its value in detailing Cu behavior in SCR of NO_x, but questioning its claim of practical applications for fast SCR in very high temperatures. It is unclear why reduction half cycle and oxidation half cycle kinetic parameters could not have been tackled and included in the deliverables in the first 3 years of this investigation.

Reviewer 4:
The reviewer found that good progress has been made in terms of clarifying the origin of the CI phenomenon and refinements of the reduction/oxidation half-cycles to better match with reactor measurements. Given that many SCR models reported in the literature were developed based on steady-state data, the reviewer inquired about the important features/aspects that are missing or incorrectly captured in the steady-state data-based

models. Such information would help advance SCR modeling, but cannot easily be extracted from the presentation slides.

Reviewer 5:
The reviewer detailed this approach relies on accurately measuring the NO_x response of a catalyst when NH_3 is turned on. This may be challenging, given the wide range of exhaust conditions. Also, determining the state of an SCR using this method will require using field aged catalysts as reference catalysts, not oven aged. Also, the effect of poisons must be known. The reviewer found that in general, the characterization work forms a good basis to explore this concept further.

Reviewer 6:
The reviewer said model developed seems to be able to simulate the behavior of CI shown in Slides 21 and 22. However, the reviewer is still not sure how quantitatively accurate the model is. Still, the reviewer found this to be good progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer remarked the close working relationship between Cummins and ORNL allows this to be an extremely successful project. The fact that Cummins is the sole provider of the modeling work, which is crucial to this project, demonstrates the tight integration of the research. The reviewer commented that the separation of the task responsibilities gets the most out the strengths of each of the partners.

Reviewer 2:
The reviewer found that partnering with Cummins for HDD aftertreatment is a very good choice. However, having more sensor and catalyst suppliers involved would benefit the project and should provide greater insight on accurately measuring the NO_x and NH_3 in a vehicle application and to characterize the catalyst appropriately.

Reviewer 3:
The reviewer stated that the team is a CRADA, including ORNL and Cummins, and the team appears to be collaborating well. The reviewer suggested that the team including just two partner may be a challenge.

Reviewer 4:
The reviewer observed good team work between the project team and the industry partner. The reviewer found that the work borrows well from the leading edge analyses in the literature. Given the work novelty, the team could have benefited from investigators at Purdue or Notre Dame. The reviewer said though no formal collaborations were established (as a part of this project), the team appears to be aware of such works and has been following them.

Reviewer 5:
The reviewer stated that this project has good collaboration between ORNL and Cummins.

Reviewer 6:
The reviewer commented that Slide 24 shows the collaborations and coordination.

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 as with all good projects, the future research falls naturally out of the work already done. The reviewer sees nothing to suggest a missing element in the proposed future research.

Reviewer 2:
The reviewer said this project ends at the end of FY 2018, so the research plan appears to be locked in for this project. The future tasks proposed are all logical next steps of the current work. The reviewer recommended emphasizing the work on the two half-cycle kinetics and the effects of aging on those kinetics. At some point, engine testing will be necessary to evaluate the relevance of these new models to real, fielded systems. The reviewer said please consider adding this task to your scope of work for the next CRADA project.

Reviewer 3:
The reviewer remarked the team has a good plan for future work and for extending the existing work into emission control modeling and on-road applications.

Reviewer 4:
The reviewer recommended that this project should give more attention to field aged catalysts to understand if there are differences in the aging mechanisms that are not captured in oven or dynamometer aged catalysts. Normal operating conditions will expose the catalysts to many difference deactivation mechanisms. The reviewer strongly encouraged continued characterization work.

Reviewer 5:
The reviewer said it would be of practical value to integrate the SCR kinetic model developed here with a catalyst thermal model and simulate NO_x emission as a function of FTP time during engine dynamometer/vehicle tests to demonstrate the advantages of the kinetic model developed in this project.

Reviewer 6:
The reviewer found that the presentation did not give much mention regarding the future work, because the program seems to be completed at given funding.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said the developments from this project have moved smoothly into the development and even production phases of aftertreatment development.

Reviewer 2:
The reviewer pointed out optimizing the fuel and reductant use to obtain the required amount of emissions control is a primary objective of OEMs. The reviewer commented that this work supports that goal.

Reviewer 3:
The reviewer pointed out that modern and future ICEs will continue to need exhaust aftertreatment systems to ensure that criteria pollutants are within limits.

Reviewer 4:
The reviewer commented the project goal, focused on understanding SCR fundamentals, supports DOE's objective for more efficient emission control technologies. Because higher SCR of NO_x is synonymous with

higher engine-out NO_x, itself a means for fuel saving, this undertaking could potentially be integrated in better SCR of NO_x and hence into higher engine-out NO_x yielding fuel savings.

Reviewer 5:
According to the reviewer, lean-burn systems, including diesel engines, are fuel efficient, and improved SCR performance would be critical to their widespread use in the market.

Reviewer 6:
The reviewer said this project can help improve our knowledge on catalyst behaviors, thus developing a better control strategy to improve fuel economy

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 this CRADA always seems successful with the funding that they have.

Reviewer 2:
The reviewer commented that the resources and funding appear to be adequate.

Reviewer 3:
The reviewer said the team appears to have met their objectives with the available budget and other resources.

Reviewer 4:
Continuing the modeling phase, the team is to explore kinetics and to check impact of aging, composition and such on the Cu state. The reviewer found that resources are sufficient.

Reviewer 5:
The reviewer remarked that the resources seem sufficient to carry out the tasks specified.

Reviewer 6:
The reviewer said the project seems to be completed as scheduled.

Presentation Number: acs033
Presentation Title: Emissions Control for Lean Gasoline Engines
Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Presenter
Todd Toops, Oak Ridge 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 and well-planned.

Reviewer 1:
The reviewer stated that the approach on this project has evolved well in its 3 years. Evolution of goals and responses is highly expected for such an inherently complicated system with many relevant variables. The approach and the results have led to very useful understanding.

Reviewer 2:
The reviewer commented that the need to address U.S. Environmental Protection Agency (EPA) Tier 3 Bin 30—also known as the 150°C challenge—was clearly highlighted, as was the need to do so within the context of total cost of ownership (TCO). The project also clearly conveyed the role of lean-burn gasoline in achieving this target. The reviewer described the team approach as rational, logical, and a good balance of catalyst development and engine management strategy to ensure synergistic optimization of diverse elements. The application of an iterative development strategy with multiple points of feedback between the researcher, the washcoater and the OEM, to enable discussion and cross-fertilization, was exemplary.

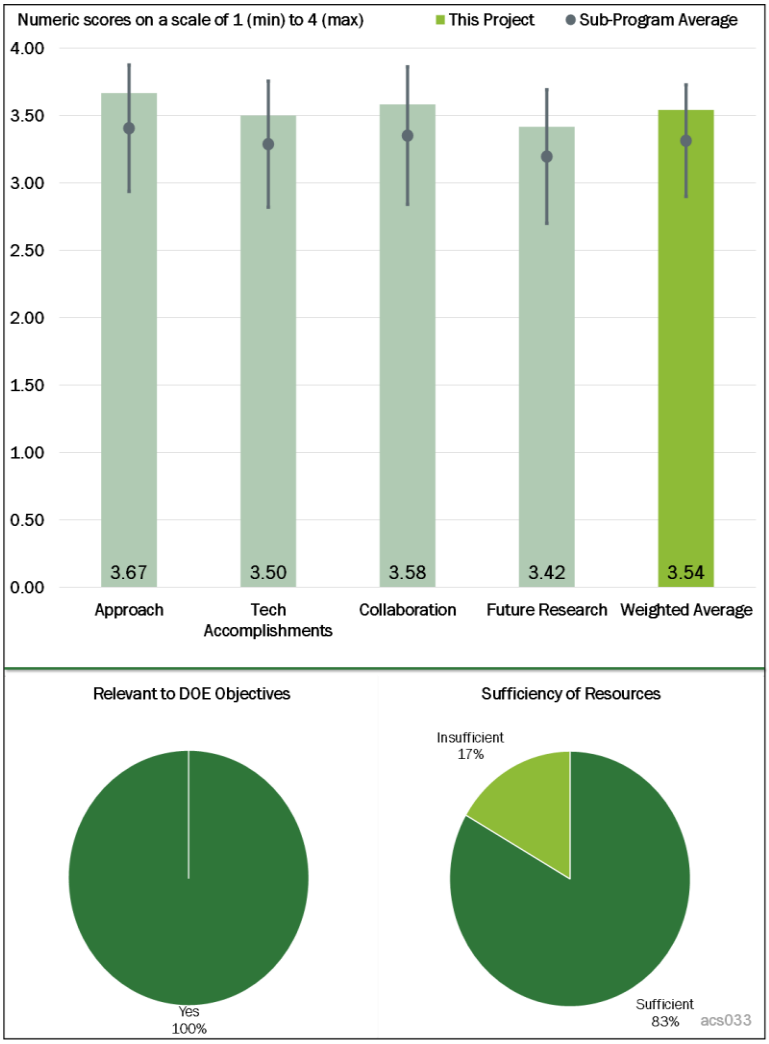

Figure 1-16 - Presentation Number: acs033 Presentation Title: Emissions Control for Lean Gasoline Engines Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Reviewer 3:
The reviewer said that the approach is well-defined and the researchers have incorporated previous reviewer suggestions in their work.

Reviewer 4:
The reviewer noted that this project directly addresses multiple U.S. DRIVE ACEC barriers. Regarding the first bullet on Slide 23, adding another catalyst may not be welcomed by industry. A zone-coated SCR catalyst might be more promising.

Reviewer 5:
This reviewer described using the BMW engine for lean-burn research as good work. One issue with the engine is that it emits a high level of O_2 during rich operation, which requires using richer A/F ratios to produce NH_3 over the three-way catalyst (TWC). The reviewer explained that this generates the issue with carbon monoxide (CO), although the O_2 during rich operation probably helps with the hydrocarbon (HC) control. Having an engine with less O_2 during the rich periods allows one to operate less rich to make NH_3 while mitigating the CO problem and simultaneously saving fuel.

Reviewer 6:
The reviewer commented that this project is aimed at developing an enabler for widespread use of fuel-efficient lean gasoline engines, for which no cost-effective, reliable, production-ready emission control systems are currently unavailable. The reviewer observed that the project looked into the practical new synthesis from the material development perspective. In the meantime, the team examined on the system level the feasibility of the improved aftertreatment architecture. The project is well-designed overall. The reviewer had minor questions of the project plan, including if a downstream SCR converter will survive a gasoline aging atmosphere, and of how wide the beneficial temperature window is, suggesting more investigations.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer indicated that it is commendable that 0.03 g/mile HC plus NO_x was achieved while saving almost 6% fuel. The optimization work on the ceria content was very interesting. The reviewer offered congratulations on examining the effects of sulfur on the NH_3 production.

Reviewer 2:
The reviewer commented that a range of results have come together well in this project. One of the specific findings in this project, especially with the combination of bench and engine studies, is the issue of NH_3 formation after long lean periods that need to be dealt with.

The reviewer explained that adding the six-mode test from GM and the development of a modified operating strategy more clearly showed the possibilities for passive SCR, especially if the CO cleanup is improved. That the CO emissions are a clear part of the picture is an important accomplishment.

Reviewer 3:
The reviewer thought that the technical accomplishments were good. The fuel efficiency gains after addressing the particulate emissions through use of GPF and CO slip remains to be seen. This reviewer commented that the team should show some pathway to optimization leading to a fuel efficiency gain higher than a 5%-6% gain.

Reviewer 4:
The reviewer remarked that the project appears to be proceeding on schedule. Project goals align well with U.S. DRIVE.

Reviewer 5:
This reviewer commented that a trade-off impact for ceria components for H_2 and NH_3 generation has been reported systematically, and also noted that sulfur impact to the specific aftertreatment system design has been adequately investigated. Engine operation strategy examination has been initiated and modifications are under evaluation. Overall, the reviewer has seen good progress on various key facets, but breakthroughs have yet to be concluded.

Reviewer 6:
The reviewer remarked that clear progress was demonstrated in both catalyst formulation and (sub) optimization of the engine management strategy required to fulfill the targets of the project for both cost and performance. The team has integrated a mixture of bespoke and commercial catalyst offerings to achieve significant improvement in emissions while maintaining a significant fuel savings benefit and have done so while operating within the appropriate cost structure. The reviewer indicated that work on structure function optimization within the TWC (e.g., with regard to the role of ceria and the relative contributions of H_2 [from water-gas shift]) versus CO and HC is insightful and guides the pathway for next developments well. One suggestion would be to examine the possibility of "adsorbate assisted interaction" which can occur between adsorbed NO_x or sulfur oxide and the more reactive HC species, e.g., C_3H_6 or aromatic. This reviewer suggested that a further opportunity for improvement would be further tuning the lean/rich strategy of the engine to concentrate rich phases on the natural acceleration modes of the drive cycle. This would result in more and potentially deeper rich phases, but with a general increase of the total net lean character of the integrated driving cycle. The reviewer added that this would mitigate against the rich NH_3 plume seen at approximately 280 s and would decrease the multiple CO and late-stage HC spikes noted in the tailpipe.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer highlighted that collaborators were very informed and relevant to this project, with one OEM and one catalyst company, along with the University of South Carolina.

Reviewer 2:
The reviewer stated that the team is well-rounded with strong presence from academia, and OEM and washcoater, and that this is a clear strength of the project. The techniques and tools are obviously derived from coherent discussions and agreement, reflecting the strengths of the various partners.

Reviewer 3:
The reviewer observed very good collaboration, with nothing more to suggest.

Reviewer 4:
The reviewer remarked that there appeared to be very good collaborations with GM, Umicore, and other industrial representatives.

Reviewer 5:
The reviewer observed that the project appears to be well-coordinated across multiple partners in industry, national laboratories, and academia.

Reviewer 6:
The reviewer noted that the principle investigators (PIs) have had close interactions with an OEM (GM) and catalyst supplier (Umicore).

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 future planned research addresses the current barriers including CO slip.

Reviewer 2:
The reviewer stated that the future plan of evaluating passive SCR system architecture to maximize fuel savings while meeting Tier 3 emission regulations remains a solid path forward. The potential risk is the team needs more work force to fulfill the tasks on time, as the PI pointed out.

Reviewer 3:
The reviewer acknowledged that the future work is ambitious with a clear pathway. However, this reviewer would caution the team on developing an overly complex system as this naturally lends the overall package open to a larger number of failure modes with increasing interdependency. For example, the "heat sink" catalyst could be removed through better use of energy management system (EMS) strategies to provide both the correct lambda for the system and the appropriate operating temperatures.

Reviewer 4:
The reviewer noted that understanding the factors that could lead to improved fuel economy while still meeting Tier 3 standards is a significant goal to meet before the project is completed.

Reviewer 5:
The reviewer asserted that the future work addresses some key remaining tasks, such as exploring pathways for additional fuel efficiency gains, and improved catalysts and addressing particulates. The reviewer also remarked please consider demonstration on vehicle and transient testing on certification cycles such as Federal Test Procedure (FTP) and US06 to cover a broad range of operating conditions.

Reviewer 6:
The reviewer said that the PI might want to investigate the effect of the rich-side O_2 level on the system performance, at least on the laboratory reactor. With less O_2, the engine can operate less rich to generate NH_3, which will cut down on the CO emissions and fuel consumption.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that the approach is well-reasoned and sound. The team has demonstrated good progress with clearly evident substantive deliverables. This has been achieved through both individual contribution but also as a function of a cross-functional effort and understanding. The project itself is highly relevant and timely and may offer significant breakthroughs and benefits of high commercial and societal value.

Reviewer 2:
The reviewer reported that this project is well-aligned with DOE goals, particularly those outlined in the U.S. DRIVE ACEC roadmap.

Reviewer 3:
The reviewer stated that the investigations into lean operation are intended to improve fuel economy while meeting stringent emission standards. The project definitely supports DOE objectives of reduced fuel consumption.

Reviewer 4:
The reviewer expressed that, more than many projects, this project clearly looks at the barriers to improving fuel economy with a new strategy for meeting standards with a lean gasoline system.

Reviewer 5:
The reviewer affirmed that, yes, this project takes on one of the most important barriers for adoption of lean burn gasoline technologies, which could offer double digit fuel efficiency gains.

Reviewer 6:
The reviewer said that this project aims at developing an enabler for increasing brake engine efficiency, reducing aftertreatment system cost, and meeting EPA Tier 3 Bin 30 emission standard.

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

Reviewer 1:
Of the various projects reviewed in this meeting, this was one of two that the reviewer believed offered the highest potential for a game-changing outcome. To achieve the next level of demonstration—a catalyst/EMS strategy with commercial application—it is clear that more resources will be required.

Reviewer 2:
The reviewer said that the project is meeting its milestones using the supplied resources.

Reviewer 3:
The reviewer acknowledged that the resources seem to be sufficient for the current workload.

Reviewer 4:
The reviewer noted that the resources seem to be sufficient, and that the progress has been satisfactory and in a timely fashion.

Reviewer 5:
The reviewer commented that resources for the project overall appeared sufficient, but it was clear that headcount may have not been sufficient to do all that was desired.

Reviewer 6:
The reviewer observed that contribution from University of South Carolina seems to be less profound if compared with the OEM and catalyst supplier's involvement.

Presentation Number: acs052
Presentation Title: Neutron Imaging of Advanced Transportation Technologies
Principal Investigator: Martin Wissink (Oak Ridge National Laboratory)

Presenter
Martin Wissink, Oak Ridge 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 and well-planned.

Reviewer 1:
The reviewer said that the data collected in the past year shows direct relevance to DOE objectives and provides interesting insight into fuel injection processes. The insight into ball movement and multiple-injection behavior was particularly interesting to this reviewer. The modeling of the imaging technique was a good way to understand the data and the companion data from the X-ray imaging work being done at Argonne National Laboratory (ANL).

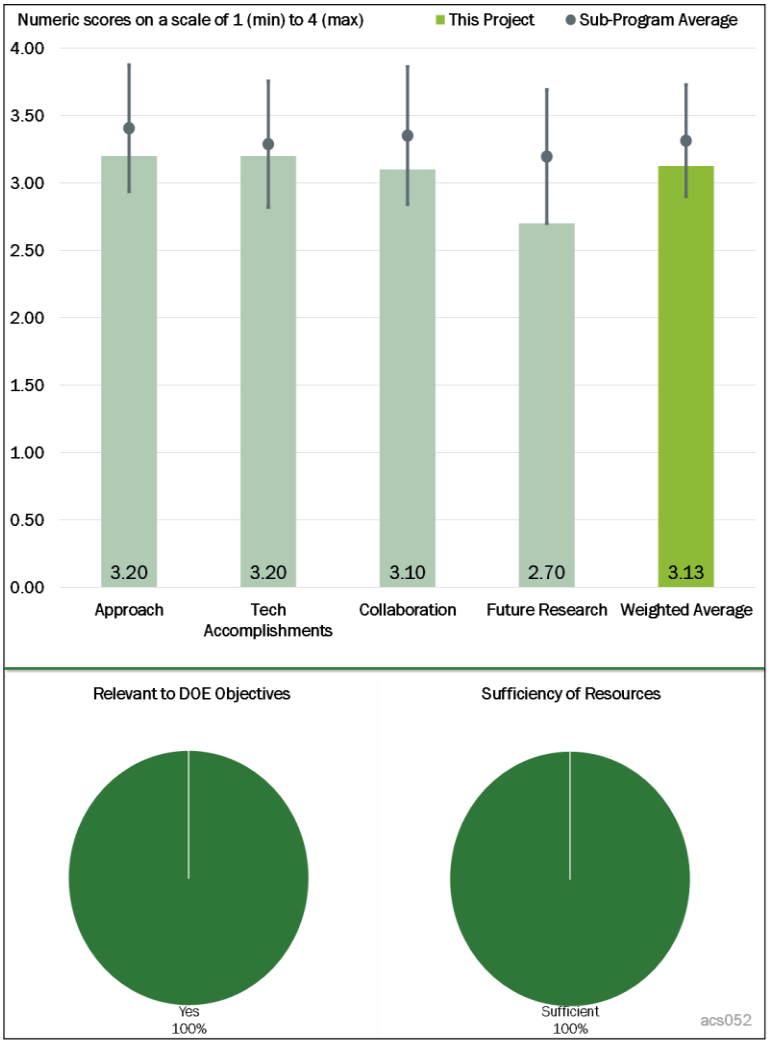

Figure 1-17 - Presentation Number: acs052 Presentation Title: Neutron Imaging of Advanced Transportation Technologies Principal Investigator: Martin Wissink (Oak Ridge National Laboratory)

Reviewer 2:
The reviewer stated that the development of neutron scanning of engine components is a good approach to expand diagnostic techniques.

Reviewer 3:
The reviewer commented that the approach to this work is good. The main reason this is good rather than excellent is that the pathway to achieve increased neutron resolution is not clear. This may be a real barrier in the experimental quantification of things like fuel injectors. If the project can clearly outline the requirements and resolution and formulate success criteria, this would help. The reviewer concluded that using the approach of combining the neutron imaging data with other information, like the X-ray data, is very good.

Reviewer 4:
The reviewer observed that most of the barriers to high-efficiency engines are due to the inability to meet emissions standards. This project increases understanding of particulate filter performance and regeneration. The diagnostic technique also has potential to improve understanding of the internal dynamics of fuel injectors. All of this information is obtained nondestructively.

Reviewer 5:
The reviewer indicated that this project is very fundamental in nature and attempts to advance the science of neutron imaging techniques and its application to ICEs. The work on the injector is very unclear while the work on the aftertreatment system is very encouraging in understanding the mechanisms of soot deposition and oxidation behavior. The injector work is vague as it is unclear what experimental data are available for model development (e.g., cavitation, droplet behavior etc.) or in general, for furthering the science of sprays/combustion.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that the technical accomplishments look to be completed and on track. This project is clearly demonstrating what the current neutron imaging capabilities are and looks to have no problems with engaging the basic science community on improving/aligning the neutron diagnostic toward advanced vehicle technologies.

Reviewer 2:
The reviewer commented that progress over the past year towards the three stated goals has been good. Coordination with the ECN elevates the impact of this work.

Reviewer 3:
The reviewer indicated that the fluid dynamics of several injectors and operating conditions have been understood better with the technique. The team completed a CT of the ECN spray G injector body, and imaged a double injection event. The team procured a large single-hole injector from Bosch to aid in improving resolution of the flow dynamics. The displacement and oscillation of the needle is visible during and after injection. The reviewer further noted that an attempt is being made to quantify the movement. The team obtained more information on GDI particulate characteristics. Soot cake thickness as a function of fuel, length down the channel, and degree of regeneration was accomplished.

Reviewer 4:
The reviewer offered that the imaging results of the fuel injector lack adequate resolution and detail to make strong conclusions. The pintle wobble results seem like a real stretch of the technique. The still shots of the injector cross section are very sharp, but the movies look like fuzzy blobs. The reviewer questioned what could be done to improve resolution for the movies. The reviewer, however, found very interesting and useful results from the GPF soot cake measurements.

Reviewer 5:
The reviewer noted that the technical accomplishments are in general on track; however, it is unclear how the injector data can be used for understanding spray evolution, combustion, and emissions formation. The reviewer questioned whether some of the future experiments could be performed in a combustion constant volume chamber or a flow reactor for understanding combustion and emissions formation. The technique can be used for studying and characterizing performance differences between injectors (e.g., one injector leading to higher HC or soot emissions as compared to another injector). Measurements of dribble can lead to the understanding of HC formation in the expansion stroke.

The reviewer stated that the team should eventually tie this research to combustion experiments. With the proliferation of SCR for both gasoline and diesel combustion, the reviewer recommended studying urea injectors for understanding urea deposit formation mechanisms. Because this project is led ORNL, which has an excellent catalyst/aftertreatment team, please look for internal collaboration opportunities that can provide additional value to the scientific community. The reviewer asked if this technique could be used to assess the degradation of thermal barrier coatings (TBC) (periodic or continuous non-destructive method of TBC

thickness measurement) in an engine. This may shed some light on failure mechanisms of TBCs as different TBC materials are being tested in the research community.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that collaboration seemed to be very good in this project. It is likely no small feat to bring the basic science community together with the vehicle technology researchers and other DOE projects. Continued collaboration is encouraged to define what the success criteria are for the different technology imaging and diagnostic areas.

Reviewer 2:
The reviewer observed that this project had good collaboration.

Reviewer 3:
The reviewer noted that good collaboration exists with OEMs and fuel injection system and injector suppliers.

Reviewer 4:
The reviewer observed that there is a high degree of collaboration between academia, industry and national laboratories. The reviewer recommended including Delphi as one of the collaborators in the future.

Reviewer 5:
The reviewer asserted that the mechanisms for coordination were not clearly explained in the presentation. The coordination with ECN is a good start; however, the reviewer questioned if this is being done and what processes are in place to maximize the impact of the imaging work being done at ORNL. The reviewer also asked if the collaboration was mostly with simulation groups or with others as well. Additionally, the coordination with ANL's X-ray imaging could be more clearly explained and/or stronger as the two datasets seem to be complementary. It seems as though the imaging being done with neutrons and with X-rays is happening at very different length scales (entire injector with neutrons and just the tip with X-rays). The reviewer suggested that if the techniques are complementary, it might be beneficial to image the same injector at similar scales and combine the resulting data.

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 was glad to see plans to increase contrast for injector measurements. The reviewer asked if there are any other engine components that would be interesting to image with neutrons.

Reviewer 2:
The reviewer remarked that the future tasks and work look to be good and laid out in a reasonable fashion. The authors could more clearly outline decision points and this may help to guide the program. For example, if the imaging technique and resolution can only provide X and Y is needed, this may help guide and communicate course changes in the future work. Right now, this is still a very new application for neutron imaging, so it is difficult to criticize what is not known.

Reviewer 3:
The reviewer suggested looking for internal collaboration opportunities for using the technique for urea injectors, which may shed some light on deposit formation mechanisms. In addition, once some level of maturity with the technique has been achieved, the reviewer offered that including some combustion

experiments (or at the very least, vaporizing sprays) in a spray chamber can shed some light on equivalence ratios, combustion, and emissions formation mechanisms.

Reviewer 4:
The reviewer observed that not a lot of clarity was provided on the future directions of this research. It seems as though there are some loose ends to tie up from the current work, including more imaging of the multiple-injection strategies and imaging throughput increases. However, the longer-term vision for where this needs to go as *research*, not just a tool, was not made clear in the presentation. The reviewer asked what new scientific, or even engineering, questions can only be answered with this type of imaging. It was unclear what breakthroughs the team is planning on working towards in their proposal for the FY 2019 lab call. These questions must be answered more clearly to identify where the core value of this research is going forward.

Reviewer 5:
The reviewer reported that it is not clear as to what is next after the stated list of future work to quantify the needle and ball motion.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that this project supports the DOE goals by providing fundamental understanding of fuel injection, engine, and aftertreatment operation and performance. This understanding and knowledge can then be applied in simulations for industrial use and or industrial contract work.

Reviewer 2:
The reviewer stated that this research provides important information about sprays and injector dynamics for advanced combustion strategies.

Reviewer 3:
The reviewer noted that this project improves understanding of fuel injector dynamics and thus their effect of spray characteristics. This project also provides more understanding of particulate filters. Both these components are key in maintaining and improving the fuel efficiency of engines.

Reviewer 4:
The reviewer affirmed, yes, the project supports the DOE objectives, but is at a low technology readiness level (TRL) scale, which is fine. The project is definitely moving the needle of a new imaging diagnostic.

Reviewer 5:
The reviewer observed that neutron imaging has shown insights into the behavior of soot in GPFs, which is useful to engine manufacturers. The application of the fuel injector imaging is less clear.

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 resources seem sufficient for the proposed outcomes. Funding for detector development was good, as are the funding levels for the work itself.

Reviewer 2:
The reviewer observed that the resources are sufficient considering an increase in funding in FY 2018 for detector development. This is the key area where this neutron imaging likely needs to improve for vehicle technology research.

Reviewer 3:
The reviewer stated that the funding is adequate.

Reviewer 4:
The reviewer highlighted that it sounds like beam time availability is not an issue anymore. Further, the reviewer said that resources are sufficient.

Reviewer 5:
The reviewer asserted that the FY 2018 budget of $300,000 is reasonable for the project.

Presentation Number: acs054
Presentation Title: Rapid Compression Machine (RCM) Studies to Enable Gasoline-Relevant Low-Temperature Combustion
Principal Investigator: Scott Goldsborough (Argonne National Laboratory)

Presenter
Scott Goldsborough, 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 and well-planned.

Reviewer 1:
The reviewer noted that this project supports several other VTO projects, such the development of surrogate fuel chemical kinetics. The project is properly managed and the PI demonstrated progress from last year.

Reviewer 2:
The reviewer commented that RCM work is useful to establish kinetic fundamentals. Coordination with others through the workshop is useful.

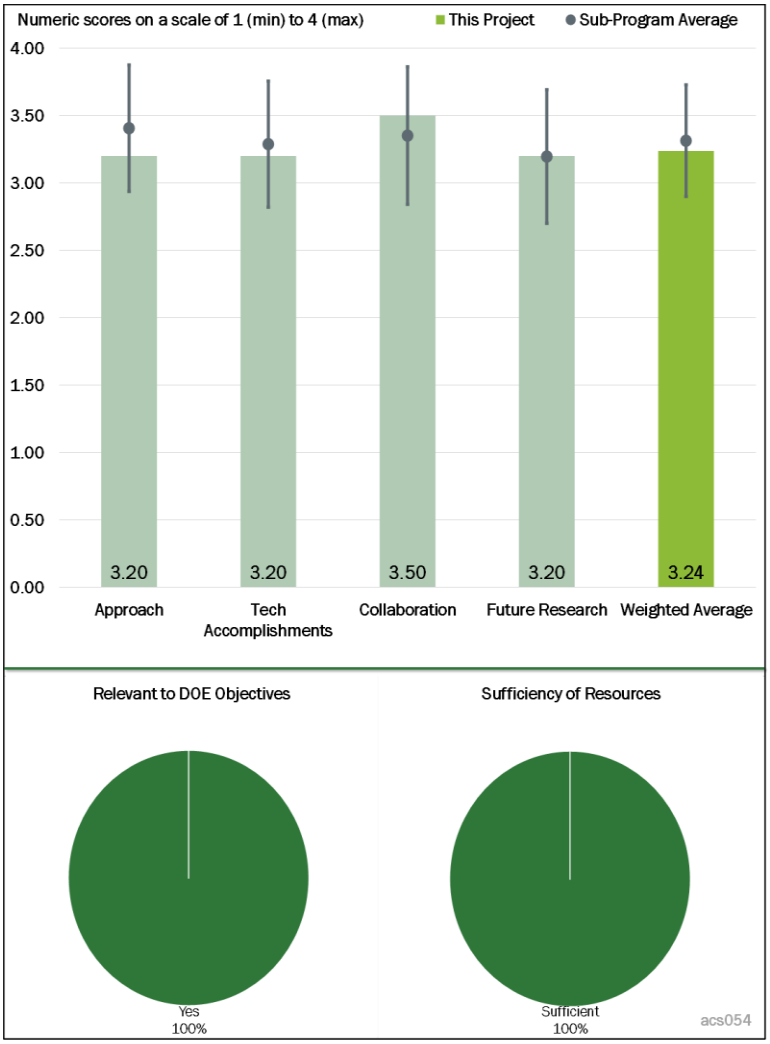

Figure 1-18 - Presentation Number: acs054 Presentation Title: Rapid Compression Machine (RCM) Studies to Enable Gasoline-Relevant Low-Temperature Combustion Principal Investigator: Scott Goldsborough (Argonne National Laboratory)

Reviewer 3:
The reviewer stated that the approach is laid out clearly and effectively. The reviewer had nothing much more to add.

Reviewer 4:
The reviewer believed that the technical barriers either have been or are being addressed, depending upon the specific barrier. The RCM project is well-designed and feasible.

Reviewer 5:
The reviewer suggested that the project should begin studying individual fuel molecules for properly deriving functional-group methodology, before studying complex mixtures such as surrogates.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed good accomplishments and progress in modeling and testing. Organizing the RCM workshop is a great move and contribution.

Reviewer 2:
The reviewer stated that the project is on track with its objectives. The PI demonstrated very good progress from last year's presentation.

Reviewer 3:
The reviewer noted that good progress has been made to extend data to more representative fuels and engine relevant conditions. In particular, ethanol effects are being investigated in a useful way.

Reviewer 4:
The reviewer said it seems that the team has organized the national and international RCM community, which will enable them to establish a database of reproducible measurements.

Reviewer 5:
The reviewer indicated that the Task 1 accomplishments include acquiring an impressive amount of experimental data, which produced improved understanding of the effects of ethanol. The E10 certification gasoline experiments (Task 2) also exhibit acquisition of an impressive amount of data and the analysis of LTC and intermediate temperature chemistry regimes is of value. The presentation skips Task 3, leaving this reviewer wondering what was/is/will be the subject of that task. Only one slide is devoted to Task 4, showing some experimental results and stating—without graphics—that the comparisons with the updated LLNL model are good. A bit more detail, such as a graphical comparison, would be beneficial. The reviewer concluded that the completion of Task 5 is a commendable accomplishment.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer highlighted good collaborations all around. The PI appears to try really hard to share information with other groups and to fit into multiple subjects at multiple levels of collaborations.

Reviewer 2:
The reviewer expressed that ANL is coordinating with what appears to be all of the important contributors in this research area.

Reviewer 3:
The reviewer noted that the PI showed a lot a collaboration and coordination with the national laboratories. The reviewer was not sure how much collaboration can be done with the industry considering the fundamental goals of this project, but suggested more collaborations with U.S. universities. All the academic collaborations that the PI presented are with universities outside the United States. The reviewer did not understand how the PI does not collaborate with U.S. universities when there is so much activity in academia related to RCM work and analysis.

Reviewer 4:
The reviewer acknowledged that coordination of the workshop is a very good idea. Coordination using a MOU is also important. The reviewer questioned why there were no U.S. universities in the list of collaborators.

Reviewer 5:
The reviewer said that ANL has at least two shock tubes. These are local resources that the authors should take advantage of. The authors should strongly consider to include such shock tube results as reference for validation.

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 future work supports the VTO goal on improving kinetic mechanisms for conventional and advanced fuels. The results will benefit multiple other projects across DOE.

Reviewer 2:
The reviewer noted that project plans were developed in collaboration with modelers and engine experiments so the results will be useful and relevant.

Reviewer 3:
The reviewer asserted that the proposed plan looks promising and aligned with the milestones. It is going to be very interesting to see how computational calculations can help to figure out the facility-to-facility measurement differences.

Reviewer 4:
The reviewer said that the ANL researchers appear to have identified all of the appropriate next steps for their portion of the overall project.

Reviewer 5:
The reviewer observed that, at this point, instead of moving toward complex mixtures, the team should go back to study single compounds and model them individually. Once this knowledge is established, models can be developed from the combination of the data from the individual molecules. Mixtures can only be understood if the reactions from the individual components of mixtures are also understood.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer asserted that the project addresses uncertainties in ignition characteristics of fuel variants in advanced combustion conditions. It is very relevant to the DOE objectives.

Reviewer 2:
The reviewer acknowledged that, yes, the project supports the overall DOE objectives. Work on developing accurate chemical kinetics for real fuels is extremely important for VTO goals.

Reviewer 3:
The reviewer reported that this kind of work establishes the base of scientific data needed to develop models and experiments for improvement of engine efficiency and emissions.

Reviewer 4:
The reviewer stated that ANL's twin-piston RCM is being used to acquire autoignition data, over the appropriate ranges of engine-like conditions but without the complications inherent in actual engine tests, such as turbulence, to synergistically improve LLNL's chemical kinetics models.

Reviewer 5:
The reviewer indicated that the study mainly focuses on transportation-relevant fuels.

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

Reviewer 1:
The reviewer recommended increasing the funding to encourage collaboration with U.S. universities if funds are available.

Reviewer 2:
The reviewer said that the funding seems about right to support continuation of this work.

Reviewer 3:
The reviewer offered that it seems like the resource is just enough for the milestones.

Reviewer 4:
The reviewer stated that ANL's resources appear to be entirely sufficient for this project, as the reviewer understand it.

Reviewer 5:
The reviewer commented that the authors have organized efforts in a variety of R&D centers, crucial for validation.

Presentation Number: acs056
Presentation Title: Fuel-Neutral Studies of Particulate-Matter Transport Emissions
Principal Investigator: Mark Stewart (Pacific Northwest National Laboratory)

Presenter
Mark Stewart, Pacific Northwest 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 and well-planned.

Reviewer 1:
The reviewer noted that the researcher is developing a model to describe the particulate matter (PM) transport in a particulate filter. The reviewer believes the researcher should be commended on the length to which the team evaluated several models to develop an acceptable model for PM transport.

Reviewer 2:
The reviewer reported that, overall, this was a well-organized project focused on most of the salient issues. The project has a fundamental focus on practical issues associated with particulates collection and analysis.

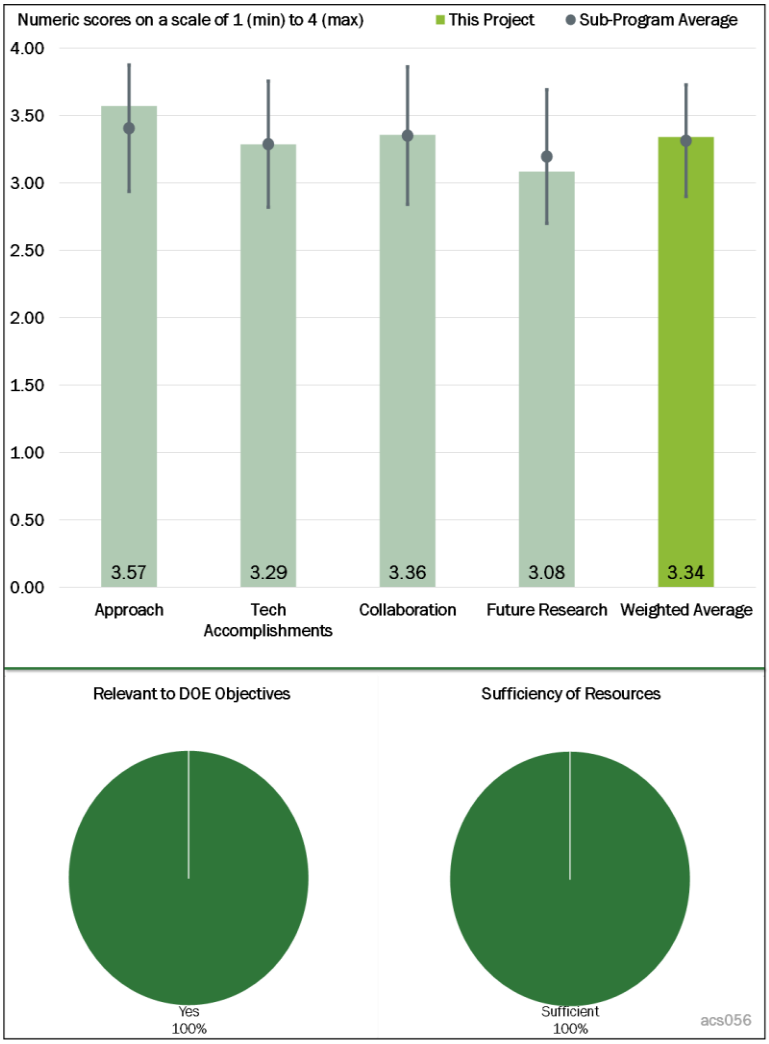

Figure 1-19 - Presentation Number: acs056 Presentation Title: Fuel-Neutral Studies of Particulate-Matter Transport Emissions Principal Investigator: Stewart, Mark (Pacific Northwest National Laboratory)

Reviewer 3:
The reviewer stated that the overall approach is excellent. The reviewer wished to emphasize the statistical nature of this project, and encourage the researchers to analyze several microstructures for a given porosity / pore size combination and present results with error bars.

Reviewer 4:
The reviewer commented that the project addresses the need for a better understanding of the underlying mechanics of filtration through both modeling and experiment. The work includes a good mix of experimental characterization and modeling/tuning. The PI has done a good job working with university researchers and developing industry relationships.

Reviewer 5:
The reviewer observed that the use of capillary flow porometry (CFP) to determine the distribution of throat sizes should be a useful tool for characterizing the different filters. It is commendable that the team is

considering ash and catalyst coating effects on the flow through the washcoat. The reviewer questioned if the model could also account for PM that accumulates between regenerations.

Reviewer 6:
The reviewer commented that the team was developing a range of models to characterize contributing DPF pore volume (filtration mechanisms, simulation of flow and PM filtration). The reviewer observed that the team is also attempting to correlate these with observations. This is a sound and well-reasoned approach. However, as highlighted by others, these simulations should focus more on the behavior of washcoated DPFs/GPFs. Indeed, a challenge would be if the models themselves could be used to anticipate washcoating distribution; moreover, how washcoat distribution could be manipulated to enhance catalyst function and/or flow distribution/filtration of the monolith. In addition, the reviewer added that there does appear to be a multiplicity of models applied to a range of filters. The reviewer requested some additional comments on the strengths/weaknesses that are required for this. The reviewer suggested an effort to produce a final model which augments the best of the various models and could be used as a predictive or diagnostic tool for OEMs, washcoaters, or system integrators.

Reviewer 7:
The reviewer indicated that this project addresses the fundamentals of PM migration and filtration for SI engine emissions. The mathematical model and the collaborative approach of leveraging experiment capabilities at PNNL, University of Washington (UW), and Massachusetts Institute of Technology (MIT) makes general sense for relevant GPF systems.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that the relatively good agreement between the experimental data and the lattice-Boltzmann model predictions is quite commendable. The development of the different models (heterogeneous multiscale filtration, cylindrical pore, constricted tube, modified spherical collector, etc.) definitely fulfills the simulation mission of Crosscut Lean Exhaust Emissions Reduction Simulations (CLEERS).

Reviewer 2:
The reviewer noted that characterization techniques for filters seem to be coming along well. The various models in development appear promising.

Reviewer 3:
The reviewer commented that to support the modeling studies, experimental facilities have been newly developed for realistic filter efficiency measurement. Multiple modeling studies have been conducted after taking the catalyst washcoat and ash accumulation into consideration. The finishing project has delivered the goals that the team committed.

Reviewer 4:
The reviewer affirmed that the progress made is excellent. It would have been good to include more statistics, analyzing more samples per porosity/pore size combination.

Reviewer 5:
The reviewer said that technically the researcher had done excellent work on the model. The work would have been technically more complete if it was validated with real engine PM emissions.

Reviewer 6:
The reviewer observed that using CFP is interesting and well-executed, as is the use of tomography. The major concerns here are the use of an overly-simplified test set-up for experimental corroboration. The reviewer looks forward to the completion of the engine re-build and more complexity in the filtration studies.

Reviewer 7:
The reviewer indicated that the team has made good progress. However, the project outputs appear somewhat limited and diffuse in terms of focusing in on the critical issues in DPFs.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer remarked that strong collaborative efforts between academia, national laboratories, and industry are evident. This has allowed strong work on the fundamentals while keeping an eye to real life applications.

Reviewer 2:
The reviewer observed that the researcher had excellent collaboration.

Reviewer 3:
The reviewer expressed it is evident that there is very good collaboration with the Engine Research Center (ERC) and MIT.

Reviewer 4:
The reviewer stated that there is a well-developed team comprising academic and OEM partners. Given the fact that most filters are coated, it is suggested that the addition of a washcoating partner to the collaboration would be advantageous and provide additional insight and feedback.

Reviewer 5:
The reviewer said that the team partners appear to be focused on collaboration and contributing to the overall project success.

Reviewer 6:
The reviewer commented that a continued collaborative effort with university and OEMs is appreciated.

Reviewer 7:
The reviewer offered that it will be good to get confirmation from a substrate manufacturer and catalyzer on the results obtained.

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 program is ending; however, the researcher did lay out a pathway to complete the work. The reviewer would have rated this a four if the work was continuing.

Reviewer 2:
The reviewer commented that even though the project is ending this year, there appears to be solid amount of work planned with the CFP work, the EFA work, and the collaborative work with Justin Kamp at MIT.

Reviewer 3:
The reviewer said that the end of project appears to have been effectively planned. As for the impact of ash, integrating ash chemistry interactions with substrate properties would be highly beneficial in advancing the value of this analysis. MIT, Volvo, Lubrizol (Ewa Bardasz), and Aerosol and Particle Technology Laboratory have done a fair amount of ash chemistry analysis, which could be of great value to this investigation.

Reviewer 4:
The reviewer highlighted that while this project is closing, it will be useful to demonstrate a path to extending the pore scale analysis to filter scale, and to include some work on statistics (multiple samples for similar porosity/pore size).

Reviewer 5:
The reviewer noted that the plan for the next phase of the project (if funding will continue) is solid and reasonable from a modeling perspective. However, a potential risk is the lack of experimental studies from other groups or literature to support the future studies on multi-functional devices.

Reviewer 6:
The reviewer reported that the project focused correctly on completing tasks in hand. The reviewer further suggested that seeking input and feedback from a coater would enhance this aspect.

Reviewer 7:
The reviewer warned that the challenges do not look like they will be met with the planned future work.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that the project has excellent alignment with overall DOE objectives.

Reviewer 2:
The reviewer noted that, yes, this project helps to improve fundamental pore space characterization and will ultimately help improve performance of filters.

Reviewer 3:
The reviewer remarked that this project is relevant to DOE goals because it is a technical enabler for more efficient, less restrictive particulate traps, which will enable higher fuel economy.

Reviewer 4:
The reviewer commented that the project has a sound and structured approach to the R&D. It is making good progress in producing models to address specific aspects of the challenges in the field of PM filtration with good coordination and collaboration with external partner (except for a washcoater). The work will have direct impact and input into the field of PM filtration and the future focus on diesel is certainly appropriate.

Reviewer 5:
The reviewer observed that the project goals align well with portions of the U.S. DRIVE ACEC roadmap.

Reviewer 6:
The reviewer said that all engines (including advanced engine and combustion concepts that provide reduced fuel consumption) may need GPFs to satisfy the most stringent PM standard of 1 mg/mile. Thus, there will be a need in the future for good models of GPFs to help design exhaust systems that satisfy strict emission standards.

Reviewer 7:
The reviewer suggested that PM emission control for gasoline engine exhaust is critical as the USCAR 2018 Roadmap pointed out. Fundamental and quantified understanding of factors affecting filtration mass and number efficiency is critically anticipated.

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 there were excellent resources and facilities at the partner laboratories.

Reviewer 2:
The reviewer reported that funding is well-balanced versus the scope of activities.

Reviewer 3:
The reviewer highlighted that the program is ending so the effort needs no further resources. The reviewer further recommended that more work be done in this area, perhaps at a university.

Reviewer 4:
The reviewer offered that the project appears sufficiently funded.

Reviewer 5:
The reviewer said that the resources for this project appear to be sufficient, especially because the project will be ending this year.

Reviewer 6:
The reviewer asserted that the resources are sufficient, but to improve on the statistics, more computational resource may be needed.

Reviewer 7:
The reviewer stated that the project made good leverage of the resources in current work. The possible continuation of the project may require more input of joint effort from OEMs and catalyst suppliers to provide comprehensive picture of the complicated experimental observations.

Presentation Number: acs075
Presentation Title: Advancements in Fuel Spray and Combustion Modeling with High-Performance Computing (HPC) Resources
Principal Investigator: Sibendu Som (Argonne National Laboratory)

Presenter
Sibendu Som, Argonne 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 and well-planned.

Reviewer 1:
This project was very exciting to the reviewer. It is interesting to think back 20 years to forecasts on computing power growth and the associated impact for simulation capability. It can be seen how those predictions are being achieved in work like this. Each of the subtasks in the project appear to be making huge strides in tackling significant limitations of current modeling approaches, and are showing results that bring the simulation much closer to real-world hardware performance.

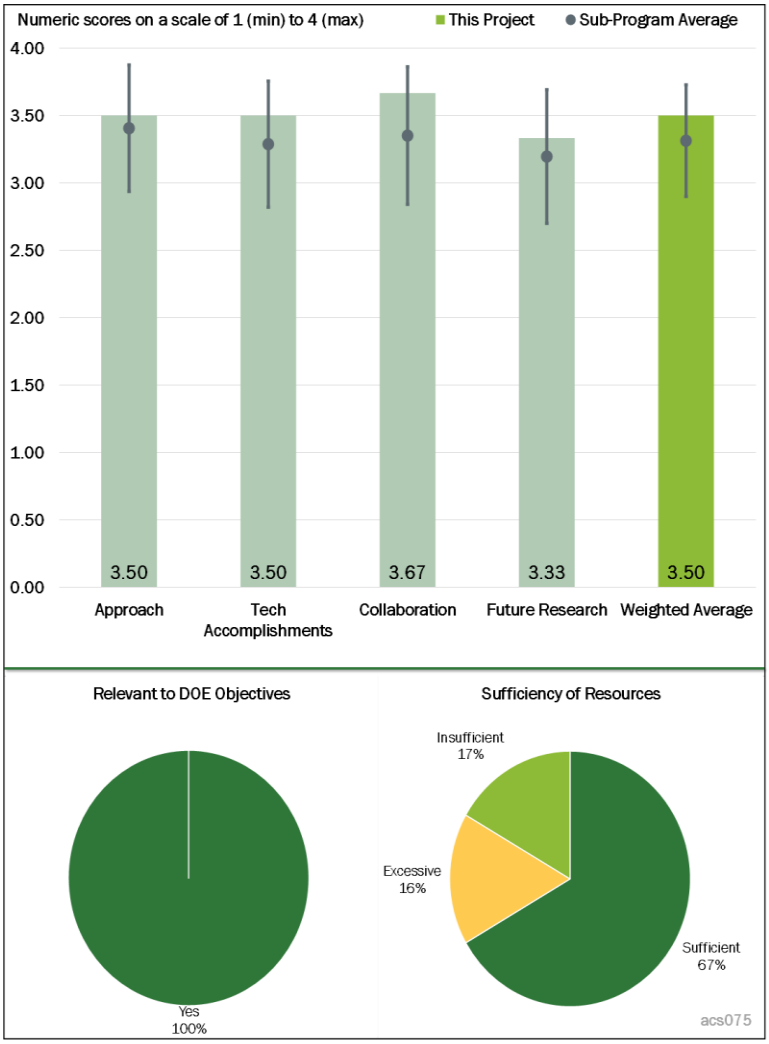

Figure 1-20 - Presentation Number: acs075 Presentation Title: Advancements in Fuel Spray and Combustion Modeling with High-Performance Computing (HPC) Resources Principal Investigator: Sibendu Som (Argonne National Laboratory)

Reviewer 2:
The reviewer stated that the project uses two ways to contribute to the community. First, high-fidelity simulations of engineering problems using HPC to reveal fundamental mechanism behind the observed phenomena. Secondly, developing engineering computational models for engine combustion simulations. Both approaches are feasible. The issues addressed by the project, including nozzle flow and its consequence in spray, SI, and turbulent combustion, are critical problems for the industry. The reviewer concluded that the project is well-designed, overall. Although it is not critical, model development using an open-source code will be more generic, more extendable, and have a wider impact.

Reviewer 3:
The reviewer commented that the project approach is well-aligned with the technical barriers identified. It is very relevant to the community and particularly industry demands.

Reviewer 4:
The reviewer noted that the work being done by the PIs and their team directly addresses several barriers outlined by DOE. The PI made it clear throughout the presentation how each task was addressing a particular barrier, both in terms of developing further insight into physical processes as well as enhancing computational capabilities through high-performance computing.

Reviewer 5:
The reviewer observed that many resources and manpower have been invested in "computing" itself. The results for this project are very impressive. It would improve the program if there were more "physical modeling activities" to explore the physics/chemistry of the complex engine process.

Reviewer 6:
The reviewer remarked that several areas of engine combustion (sprays, ignition, turbulence, and combustion chemistry) are being addressed with state-of-the-art models and state-of-the-art computing (exascale). Sub-models for each of the key areas are being developed and validated against data from several collaborators.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed that the progress of the project is excellent. A quantity of stored energy is defined to link the cavitation phenomena with its impacts on structure. The predicted distribution of pressure and stored energy is consistent with experimental measurement, indicating that the stored energy is a good indicator for erosion. Comparison of numerical results using nominal and real geometry shows difference in spray structure. This implies that the spray is very sensitive to the geometry of nozzle, highlighting the importance of the real geometry for spray simulations.

The reviewer also stated that the Euler-Lagrange Spray Atomization (ELSA) model has been applied to simulate the multi-hole GDI injector. A discrepancy was observed in comparing the predicted velocity with measurement, even worse than simulations with return on investment. It indicates that the model needs improvement. This reviewer further acknowledged that the Lagrangian-Eulerian Spark-Ignition (LESI) model is developed for the conventional spark plug. The model has been extended to low-temperature plasma with energy and species deposition. Further development and validation over a variety of conditions are needed by the LESI model. The PIs applied artificial neural networks (ANN) for flamelet tabulation to replace the flamelet with an ANN, which significantly reduces memory usage and speeds up computation.

Reviewer 2:
The reviewer asserted that the progress on the project and the individual tasks is really good. In each of the areas, results are seen which show improved predictive performance and, in a number of cases, the tools are ready to be distributed out for use by other groups.

The only area where this reviewer would like to see additional work is in developing ways to use some of these tools in less than HPC-level computer systems. It does appear that the spray modeling is the highest CPU resource, but the detailed combustion still looks like it is fairly intensive as well (though the team has made massive strides in fixing this). The reviewer was very interested in finding out if there are ways that the team can take the learnings from these super-detailed models and use that to support development of higher-level models that capture the behavior for faster simulation speeds. The reviewer assumed that this is a totally new task or maybe even new project, but it seems like an important area to add so that the work from this project can impact industry sooner.

Reviewer 3:
The reviewer stated that significant progress has been made in the past year and results of the work are actively disseminated to the scientific community and to the industrial community through publishing and close

collaboration with outside partners. In particular, the work on nozzle geometry variation and nozzle wear has made significant strides in understanding of variability in engine combustion processes.

Reviewer 4:
The reviewer highlighted that essentially two projects have been combined. Very good progress has been made on understanding the impact of cavitation on metal damage. The location of cavitation is being predicted well. The team has modeled real versus nominal fuel injector geometry effects to show differences between the two cases. Spray droplet size differences between the two cases have been observed. The reviewer remarked that significant progress has also been made in the modeling of various ignition systems (conventional arc, tuned port injection [TPI], corona discharge).

Reviewer 5:
The reviewer said that this project has made excellent progress. Regarding the ELSA model, the reviewer questioned what was new about it, because it has been around a decade now with number of demonstrations. The reviewer did not understand if it is it taking a new development/improvement or another demonstration with needle movement, and concluded that this needs clarification.

Reviewer 6:
The reviewer commented that many sophisticated models are used within this project. The reviewer wondered if they really need to be so complex. It might be possible to devise simpler models to explore the detailed processes such that engineers can use them an effective tool. If so, then it will be an outstanding accomplishment.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer reported that the list of collaborators within the team is fantastic. There appears to be an excellent interaction both within the team and with outside partners to ensure good transfer of technology out to where it can be used.

Reviewer 2:
The reviewer indicated that the PIs collaborate with a lot of groups within ANL, with the national laboratories, universities and industries. The PIs are also very active in ECN. The reviewer further noted that the Virtual Engine Research Institute and Fuels Initiative (VERIFI) offers another platform for collaborations with industries covering engine OEMs, software vendors, oil companies, and computing service companies. Close interactions with industries ensure the right direction of their research, and bring in valuable comments from different aspects. The collaboration model is the most industry-friendly, the widest one among the DOE AEC section.

Reviewer 3:
The reviewer said that collaborations were very good.

Reviewer 4:
The reviewer affirmed that nice collaborations were utilized. The reviewer expressed concern that this work was done with a specific software. The PI will be questioned consistently, which is due to the nature of the collaboration.

Reviewer 5:
The reviewer commented that the team has close and substantial collaborations with a number of outside partners. Their collaboration with industry is particularly laudable, including both the team's work with CFD companies to enhance turbulent combustion modeling capability, as well as engine manufacturers, to support advanced engine simulation. The cooperative research and development agreement (CRADA) framework for their work with Cummins was identified as a concern by reviewers in the past, but it seems as though the

national laboratories benefit greatly from the arrangement as the collaboration provides a good foundation for doing impactful work. The reviewer further noted that this particular group publishes widely and is actively sharing with other members of industry and the academic community. The authors are also active members of the ECN, and even starting to reach out to the aerospace community, which this reviewer believes will particularly enhance their efforts in turbulent combustion modeling and ignition modeling.

Reviewer 6:
The reviewer noted that very good collaborations exist with GM, several national laboratories and universities, as well as Convergent Science. The reviewer suggested further collaboration with fuel injector suppliers who could benefit from the simulation capability to design injectors with improved spray characteristics.

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 highlighted that the PIs plan is further improvements to their models, including the cavitation erosion model, flamelet model, and ignition model. The team has planned model validation, and also plans further extending the models to different applications. The research plan is very feasible.

Reviewer 2:
The reviewer noted that it will be very meaningful to devise faster and accurate models in the future.

Reviewer 3:
The reviewer commented that the future research plans largely look good, and extend the work further from where it currently stands. The reviewer would like to see an additional task that is dedicated to transferring modeling tool function to simpler and more computationally accessible models which can be used by industry on lower performance hardware.

Reviewer 4:
The reviewer stated that the proposed future work is well organized and follows logically from the achievements from this year. Of particular importance is the integration of uncertainty quantification into the simulations, and so that addition will be important. In their work on nozzle wear and ignition, the PIs should consider including a framework for capturing the stochastic nature of these processes for better understanding the impact that these phenomena have on engine performance. For the nozzle wear issue, the reviewer reported that the project work on particular geometries is excellent and the barrier they identified at the end of their presentation (about injection versus wear timescales) is an important issue. There are methods by which the stochastic nature of wear (over the course of time and from one injector to the other) can be captured and more learned from the simulations. Similarly, the issues surrounding stochastic behavior of ignition and cycle-to-cycle variations could also be captured in future work. It would be great to see this integrated into future plans.

Reviewer 5:
The reviewer observed that all the future work proposed is good. Care should be taken to maintain a good balance between gasoline LD and diesel medium-/heavy-duty problems. However, the advised that collaboration with gasoline fuel injector suppliers should be aggressively pursed in order to have a quick impact on improving fuel spray characteristics.

Reviewer 6:
The reviewer suggested that the future research plan is more towards adding details and moving towards higher fidelity. However, the rest of the community, often, cannot afford usage of a supercomputing cluster. It would be nice if the PI could plan to fill that gap. Developing modeling capability with fewer tuning constants would not necessarily mean moving towards complex models, because then direct numerical simulation would

be used, which is not affordable by most of the community. In the same regards, it is doubtful if publications of sub models that few can implement and afford can benefit many others.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that the project intends to close the gap between fundamental research and industrial applications by developing engineering models for engine combustion simulations. The Engine OEMs are very likely to adopt outcomes of the project for engine simulation and optimization. The models may improve the accuracy or efficiency of the simulations. The project also investigates some critical issues in engine combustion using high-fidelity simulation to reveal the fundamental mechanism and improve the understanding of the process, which is very important for engine engineers.

Reviewer 2:
The reviewer stated that this project clearly addresses DOE objectives.

Reviewer 3:
The reviewer observed that it is very relevant to DOE objectives.

Reviewer 4:
The reviewer said that the project certainly supports the DOE objectives for clean energy utilization. Understanding of the internal combustion (IC) engine-related physics will help to develop advanced concepts with better fuel economy and less emissions.

Reviewer 5:
The reviewer commented that this work addresses several key DOE objectives, including both vehicle technologies and computing goals.

Reviewer 6:
The reviewer stated that predictive modelling capability is needed to design high-efficiency engines with short design turnaround times. Specifically, the accuracy and speed of simulations need to be increased.

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 reduced spending rate for FY 2018 is of great concern. This team is addressing a number of important issues. Given the difficulty of the technical challenges and the effort required to continue the productive collaborations the team has established, it would be unfortunate to see them have to reduce either their technical inquiries or their collaborations due to insufficient funds. In particular, funding for post-doctoral researchers and PI time to support these critical collaborations should be maintained at levels reflective of the expectations put on the team. The funding levels from FY 2016 seem much more reasonable than those from FY 2018, especially given the increasing spotlight put on large-scale simulation and exascale computing.

Reviewer 2:
The reviewer remarked that the funding levels and resources appear to be well-matched to the project needs.

Reviewer 3:
The reviewer acknowledged that the team has access to the world's top computational facility at ANL. The team is also backed up by the engine test team and X-ray team at ANL.

Reviewer 4:
The reviewer indicated that resources seem adequate for the project plan and milestones.

Reviewer 5:
The reviewer stated that resources are sufficient.

Reviewer 6:
With the resources the group has had, in addition to running computations so excessively, this reviewer expected more accomplishments.

Presentation Number: acs085
Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization
Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Presenter
Todd Toops, Oak Ridge 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 and well-planned.

Reviewer 1:
The reviewer observed good collaboration with both commercial and academic partners. The reviewer also highlighted good diversity over investigating a variety of applications (gasoline and diesel). This project uses a good mix of empirical and first-principle approaches.

Reviewer 2:
The reviewer noted that this approach works to extends Basic Energy Sciences -funded discovery to the engineering application in the vehicle, by evaluating new and promising materials with industrially-focused protocols developed by the CLEERS and ACEC groups. In addition, the reviewer commented that this work is extending the performance of commercial materials by clever modifications to the support materials, designed to improve surface area, activity and durability. In conclusion, the high-risk approach to novel, platinum group metals (PGM)-free metal oxides is extremely interesting.

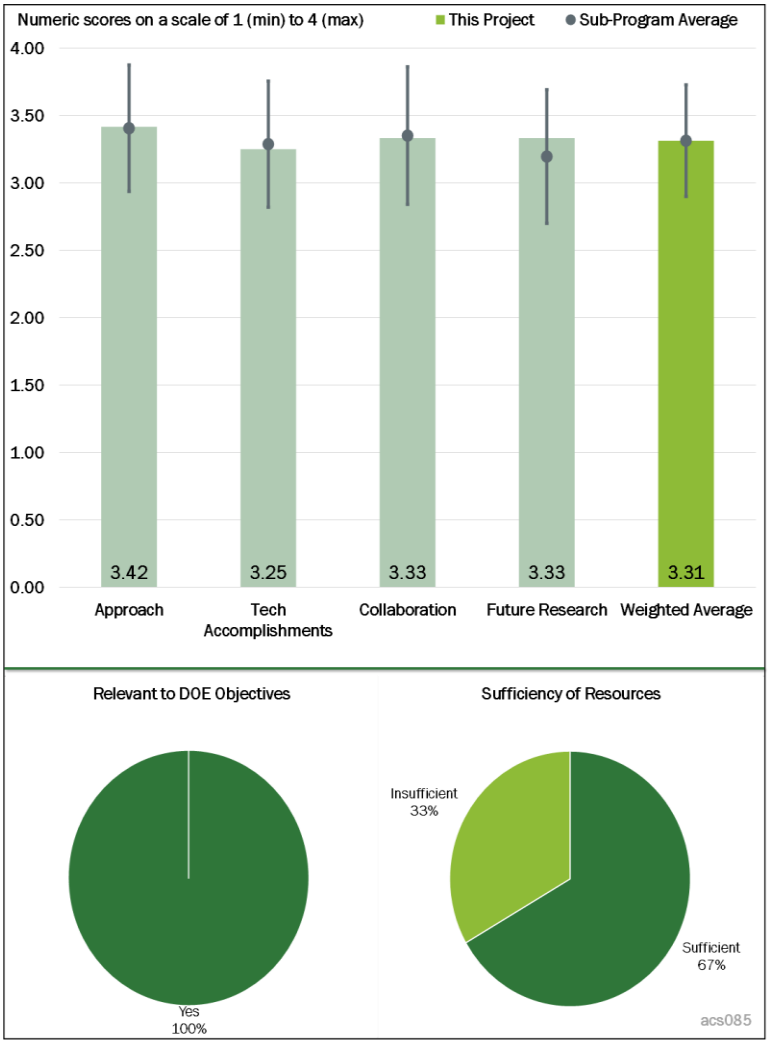

Figure 1-21 - Presentation Number: acs085 Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Reviewer 3:
The reviewer offered that the continued effort in the area of core shell and cerium-zirconium (Ce-Zr) supports the need for LTAT technologies that enable current and future engines to meet increasingly stringent emissions and fuel economy requirements. For example, innovative catalyst solutions for low-temperature oxidation of CO and HC species is strongly supported by USCAR engine and aftertreatment objectives. The inception stage exploration of multiple pathways to achieve high CO and HC oxidation performance is critical to finding viable solutions employing different catalyst technologies in a timely manner. However, the reviewer offered that incorporating poison and aging effects should be done early in the program to properly emphasize/de-emphasize potential catalyst technologies.

Reviewer 4:
The reviewer stated that the team is doing a good job of evaluating low-temperature catalysts. On-engine testing would be preferable, of course, but the reviewer recognizes that this represents a significant increase in scope.

Reviewer 5:
The reviewer reported that collaboration with multiple universities seems to generate some interesting ideas for the formulation of promising low-temperature catalysts. In addition to the activity/durability of low-temperature catalysts, this project also investigates NO_x/HC traps. With the multiple objectives and multiple collaborators involved in this project, however, it is not clear to this reviewer where this project is heading in terms of developing/validating practical low-temperature emission control solutions.

The reviewer suggested that perhaps evaluating various ideas under more severe aging conditions at early stages would help in more clearly defining the primary paths forward. 800°C aging is not severe enough for stoichiometric gasoline engine applications. Also, the reviewer noted that it would be useful to add iso-pentane and iso-octane, and examine other zeolites, beta and CHA, for HC trap evaluation. It was not clear what is being investigated under the "multifunctional catalyst evaluation." The reviewer guessed trapping plus oxidation function. If so, the reviewer questioned what is going on in the HC trap.

Reviewer 6:
The reviewer remarked that not all of the work presented here is exceptionally new. Zr has been commonly used in TWC washcoats to stabilize dispersion and enter into the oxygen storage cycle. It was not clear what was done differently here. The dual bed catalysts are interesting; however, both beds have to have the required durability for the application. The reviewer also believes silica has been added to alumina to stabilize washcoats, which is not new information.

It is well-known that ZSM-5 does not have the required hydrothermal stability. It is not clear if the CHAs have the same hydrocarbon trapping profile. For the sulfur poisoning of the dual bed catalyst, it is not uncommon for the sulfur to migrate to other parts of the catalyst. Repetitive runs would indicate if the sulfur is really removed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that the team has some nice results that provide guidance on low-temperature catalyst formulations and supports. The project also produced good results showing synergy with the dual-bed and mixed-bed systems. The materials seem to need stabilization so that they will function well out to the vehicle or engine full useful life.

Reviewer 2:
The reviewer commented that the work done by this group in the area of Pt/Pd bimetallic catalysts and highly dispersed catalysts to enhance the low-temperature CO and HC oxidation reactions is an important area to address for lean systems. However, the reviewer noted that better understanding is needed of why the bimetallic formulations did not perform as expected. The reviewer questioned if it was the sintering of the particles or the surface composition of the sintered Pt/Pd particles.

With respect to the highly dispersed PGM catalysts, the reviewer expressed that consideration should be given to the manufacturability of the materials. Many times, there is a tradeoff between the PGM cost and the production cost. If the material cannot be produced cost effectively, then it is not a viable material. If that is the case, more effort should be directed toward enhancing the activity and stability of PGM-based catalysts.

Reviewer 3:
The reviewer acknowledged good progress from this project. Some open questions remain, such as consideration of cost versus application (a balance point, a must in this cost-stringent industry), assuming commercial application is in the metrics. Aging considerations still need some work (the team may be out of time because this is the third and last year of the project).

Reviewer 4:
The reviewer observed that good progress has been made in several fronts, but moving forward, it would be necessary to pay more attention to how the team can take advantage of possible synergy between the various ongoing activates (and properly integrate) to come up with practical options for effective low-temperature emission control.

Reviewer 5:
The reviewer noted strong technical accomplishments in the four focus areas. However, the reviewer would have liked to have seen error bars on the bar plots, to distinguish the effects that are real versus the noise of the experimental measurement. The reviewer expressed excitement to see the full-size close coupled converter monolith work.

Reviewer 6:
This reviewer was concerned that the answers to some of the issues could not have been extracted from the literature or had been the subject of unpublished supplier studies. The difficulty with the unpublished supplier studies is getting some of the information from the supplier partner.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed strong collaboration between the national laboratory, University of South Carolina, and industrial partners.

Reviewer 2:
The reviewer noted that the project seems to have a good set of partners on the team, and that the ORNL-led team is drawing on the expertise from the partners.

Reviewer 3:
The reviewer said that the work presented here was in collaboration with three universities, which are the University of Buffalo, South Carolina, and Tennessee. Collaborations with other laboratories and an OEM could be improved to help minimize overlap of efforts and to better gauge the potential of the material technologies for production.

Reviewer 4:
The reviewer remarked that the team has successfully integrated both academia and industry (coaters, others) in this project execution.

Reviewer 5:
The reviewer commented that contribution/participation by Johnson Matthey Inc. (JMI) seems weak so far. Effective coordination and integration of various activities from diverse teams would remain a challenge, but this issue will become more important as the ending date of the project is approached.

Reviewer 6:
The reviewer would have preferred some OEM input to the project. It is likely some of these issues have been explored by the OEMs already.

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, in general, the direction of the future work is helpful for optimizing the activity of the catalysts for their applications. However, more consideration should be given to the processing of the material and its viability for cost effective production.

Reviewer 2:
The reviewer noted that the project is in its final year, and so most of the future work identified will need to be addressed in a follow-up project for FY 2019–FY 2021. The team should strongly consider starting to test these materials in actual engine exhaust.

Reviewer 3:
The reviewer offered that the team/project appears to have a sense of what the remaining challenges are and where they want to take this, for instance incorporating CHA (SSZ-13) into the matrix, zirconium dioxide (ZrO_2) and further aging.

Reviewer 4:
The reviewer stated that the technical work is good. The reviewer believed that other suppliers have explored some of this ground. A tighter coordination with the catalyst supplier could reduce reinventing the wheel.

Reviewer 5:
The reviewer suggested that more focus on catalyst aging and other types of zeolites in the future seems to make sense.

Reviewer 6:
The reviewer indicated that questions and feedback (particularly with respect to including lanthanum in the formulations) will be of benefit as this project moves forward.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that this is relevant inception-stage research and consistent with the call for LTAT by USCAR and the needs of the OEMs in general.

Reviewer 2:
The reviewer observed that, yes, the diversity of the team's outreach to work with industry and the needs addressed reflect this adequately.

Reviewer 3:
The reviewer expressed that high-efficiency combustion engines tend to have lower exhaust temperatures, which creates demand for catalytic converters that are active at lower temperatures. As always, demonstration of these novel catalysts on real engines will build credibility.

Reviewer 4:
The reviewer stated that viable/effective practical aftertreatment options for low-temperature emission control are an important enabler for next-generation fuel-efficient engines.

Reviewer 5:
The reviewer remarked that this project supports the DOE goals and that LTAT will be critical to the deployment of LTC engines.

Reviewer 6:
The reviewer noted that it is important to be able to reproduce some of the technology that the suppliers already have explored. It is never clear where the seams are between proprietary and commonly available 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 commented that the team seems to have sufficient resources to achieve their project objectives as planned. If engine testing is needed, though, a significant increase in budget will be needed.

Reviewer 2:
The reviewer suggested that, though the team has targeted the right challenges, given the diversity of their project needs, they could benefit from more resources.

Reviewer 3:
The reviewer affirmed that the project has made excellent progress and should continue to be funded at the same level.

Reviewer 4:
The reviewer reported that perhaps there was too much reliance on the outside collaborators. Also, the reviewer suggested that engine testing of promising technologies would require significant additional resources.

Reviewer 5:
The reviewer said that this team got a lot of work done this year.

Reviewer 6:
The reviewer noted that funding and resources are sufficient.

Presentation Number: acs093
Presentation Title: Lean Miller Cycle System Development for Light-Duty Vehicles
Principal Investigator: Paul Battiston (General Motors)

Presenter
Paul Battiston, General Motors

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 and well-planned.

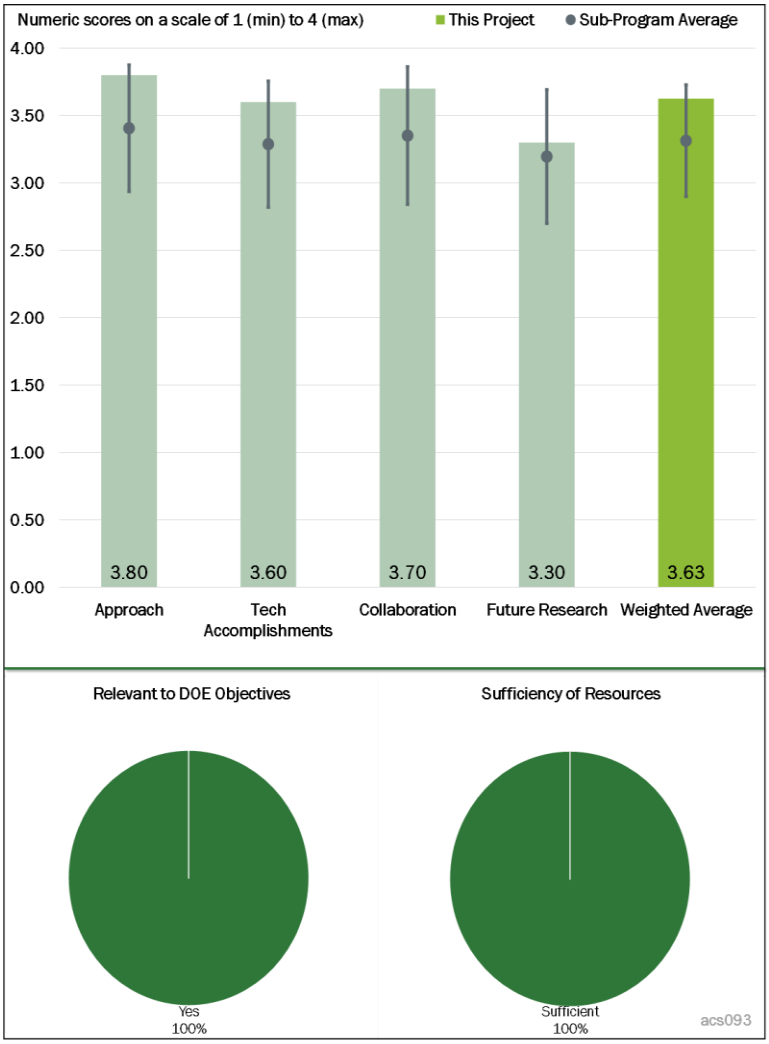

Figure 1-22 - Presentation Number: acs093 Presentation Title: Lean Miller Cycle System Development for Light-Duty Vehicles Principal Investigator: Paul Battiston (General Motors)

Reviewer 1:
The reviewer observed that the integrated approach from this team is great to see from the OEM showing strength of resources and ability to make gains at higher TRL levels. The project has a good systematic approach at technologies to increase efficiency for lean engine systems with an excellent integration approach for aftertreatment for lean burn. The reviewer remarked the presentation had a clear walkthrough of the team's efficiency gain strategy.

Reviewer 2:
The reviewer commented that this project is a very nice integration of many technologies that show promise for significant reduction in fuel consumption. Effectively doing this requires very careful matching of the operating characteristics of each component of the multiple technologies being implemented. The approach being followed here is demonstrating a systematic, fundamentally based approach to doing this.

Reviewer 3:
The reviewer noted that the approach of this project is very good. It consists of a comprehensive combustion system, engine systems (boost, valve train), and emission controls approach to reduce fuel consumption. This allows the interactions and tradeoffs to be identified, such as the interactions between efficient combustion, low exhaust temperature, air handling, and emissions control. It is a large program, and the reviewer acknowledged that there was limited time for technical detail. Given that, the reviewer would like to see the data that led to the technical decisions. For instance, the reviewer questioned what the tradeoffs are between the different air handling options, as well as what the tradeoffs are between early intake valve closing and late intake valve closing. The reviewer suggested that these findings warrant some technical papers in the public domain to document these findings.

Reviewer 4:
The reviewer said that lean gasoline combustion is of great interest to the industry and faces many challenges. GM presented a solid development program highlighting and quantifying the benefits and challenges of their approach.

Reviewer 5:
The reviewer summarized that the goal of this project is to develop an engine operating on the Miller cycle with 35% fuel economy improvement over a 2010 baseline. The Miller cycle is interesting; it is a sort of variation of the Otto Cycle. It has been around for a long time and is known to have attributes, such as more power with lower emissions potentially. The cycle is incorporated in some railway locomotives and overseas car manufacturers but apparently not yet in the United States. The reviewer also stated that the stretch goals are impressive; it is hopeful that they can be met.

The reviewer commented that the approach is well developed and carefully thought out. The link of the various components noted in the presentation to the specified fuel economy gains needs strengthening. For example, "advanced thermal management" is noted as providing a 4% gain in fuel economy. The reviewer questioned how this connection was established. Considering only the non-combustion targets, they amount to about half of the expected gains. This is significant. Even if the Miller cycle did not work out, the reviewer proposed that focusing on the other half (stop/start, thermal management, friction/mass, downsizing, etc.) would itself be worthwhile.

When the PI refers to "fuel economy improvement" the reviewer observed that two things must be established. First, precisely define what is meant by "fuel economy." Second, establish the baseline against which the improvement is compared. The latter is clear. The former is not from the presentation. The reviewer requested that in future presentations the team establish a definition of "fuel economy." If it means miles per gallon, then state it. If there is another definition please provide it. The author presented a chart that owed "efficiency," which is not the same as "fuel economy."

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted excellent technical accomplishments and progress that are directly tied to DOE and U.S. DRIVE goals. The systematic approach the team is taking is obviously paying off in terms of technical achievements. This project provides a solid approach at exploring where to focus development efforts to make largest impact on FTP. The reviewer commented that a very good approach was taken evaluating criteria on choosing boost system architecture that meets transient dynamometer and vehicle development goals that focuses on technical aspects and tradeoffs. This is a good example of enabling technology that works with the system constraints and goals. The reviewer further observed good use of CFD in driving multi-pulse injection strategy. The reviewer observed a great presentation of constraints and challenges with NO_x and HC with the lean-stratified region and comparison versus stoichiometry. The honest presentation of these data is very valuable.

Reviewer 2:
The reviewer said that good progress has been made. The team is building and installing the multi-cylinder engine in the test cell.

Reviewer 3:
The reviewer remarked that excellent progress has been made, and the reasoning behind the component choices is clear. The tradeoffs between exhaust enthalpy, engine combustion, emissions control, and air handling are very interesting. The reviewer suggested that additional disclosure of the data behind some the choices would be beneficial. For example, determining the power consumption of the ebooster would be beneficial, as would disclosure of the minimum exhaust temperature required.

Reviewer 4:
The reviewer offered that GM has made good progress on this challenging development program.

Reviewer 5:
The reviewer observed that the presentation contained a carefully thought out list of evaluation criteria with advantages noted. The use of the BorgWarner booster is interesting if cost considerations do not eliminate it. The reviewer noted several questions. First, with regard to the combustion CFD simulations that were noted, the reviewer questioned if these were carried out using CONVERGE or some other code. The reviewer also contemplated how was the spray might have been simulated. The reviewer highlighted that the spray-guided piston configuration was interesting. The reviewer questioned whether there were any constraints on the atomizer (droplet size, velocity, number density, etc.) that the team must consider to optimize performance. The reviewer remarked that the catalyst used was not clear and requested further details be provided. The reviewer questioned if any plans existed to investigate a range of catalysts. The reviewer noted that this project seems well on its way to meeting the targeted efficiency goals. The PI is already at 26% for a 2 bar brake mean effective pressure. Finally, the reviewer requested that the PI comment on the fabrication cost of an engine on overall expected vehicle cost for an engine operating on the Miller cycle. If implemented, this would be an accomplishment for both GM and DOE.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the level of integration across this project shows great collaboration. The team is well-chosen and the approach for collaboration is solid. The presentation clearly notes engagement with 40 suppliers, ORNL for lean NO_x aftertreatment and inter-GM collaborations utilizing great strengths of all involved.

Reviewer 2:
The reviewer commented that the team consists of several strong contributors.

Reviewer 3:
The reviewer said that the list of collaborators is not very long on this project, but it does include the necessary collaborators to bring this technology to the market. So, the level of collaboration is where it needs to be.

Reviewer 4:
The reviewer remarked that the project has the right mix of collaborators from both industry and other national laboratories. The author presented a list, though specifics on precisely what each provided was not given.

Reviewer 5:
The reviewer observed that to build the engine requires working with 40 suppliers.

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 proposed future work includes solid go/no-go decisions and continues a solid plan for next stages with multi-cylinder engine development. The remaining challenges also focus on Tier 3 emissions targets. The approach (Slide 8) and milestones (Slide 7) show a path to addressing these barriers.

Reviewer 2:
In the reviewer's opinion, the researchers have identified the important challenges and barriers that need to be addressed to make this work successful, and have a well thought out plan to address these challenges.

Reviewer 3:
The reviewer said that project plans are logically staged with appropriate decision points. Reasonable and sensible course adjustments have already been made, and others may occur.

Reviewer 4:
The reviewer highlighted that a list of challenges is provided for the future work that included system integration, aftertreatment work, control to manage combustion mode transitions, and others. The reviewer also noted the importance of integrating systems to achieve fuel efficiency and Tier 3 emissions targets. These are all appropriate. The proposal to optimize transient performance, control technologies, and develop a plan for vehicle implementation is good, though somewhat vague in details.

Reviewer 5:
The reviewer remarked that the project is 70% complete and most of the remaining work is focused on developing calibrations and performing multi-cylinder demonstrations. The reviewer would like to see a larger focus on reporting through technical papers. The reviewer acknowledges that there is a large portion of the data that cannot be released publicly. However, as it is an industry project, the public share of funding warrants transfer of some of the data and knowledge developed in this project to the broader technical community.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that this project clearly supports the DOE objectives and U.S. DRIVE efficiency goals and uses as project target.

Reviewer 2:
The reviewer noted that this work represents a well-run program to integrate multiple, technically advanced, fuel consumption reduction technologies into a real-world functional engine.

Reviewer 3:
The reviewer indicated that, yes, from a broad perspective it does support the overall objectives. If successful, a Miller cycle engine in a product line would be a great achievement.

Reviewer 4:
The reviewer commented that this work supports DOE goals of developing and commercializing more fuel-efficient technologies.

Reviewer 5:
The reviewer reported that a stratified lean GDI engine is very relevant to VTO goals and objectives. The speaker highlights the critical importance of cost-effective, durable and effective aftertreatment.

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 this is an ambitious project and the resources appear to be well-aligned with the efforts. Internal milestones were extended due to procurement timing.

Reviewer 2:
The reviewer commented that it appears that the funding for the program is sufficient.

Reviewer 3:
The reviewer stated that the project appears to be adequately funded.

Reviewer 4:
The reviewer remarked that this is a very large project ($21 million); however, 50% cost-share shows GM's commitment to this technology.

Reviewer 5:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Presentation Number: acs100 Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research—SuperTruck II Principal Investigator: Justin Yee (Daimler Trucks North America)

Presenter
Justin Yee, Daimler Trucks North America

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 and well-planned.

Reviewer 1:
The reviewer noted no weaknesses. The project is very well organized and systematic.

Reviewer 2:
The reviewer stated that Daimler's approach is well laid-out and delivering to the program's expectations. A good example is how the team is approaching the challenge of aerodynamics versus styling versus functionality, as well as implementing a 48 volt (V) system.

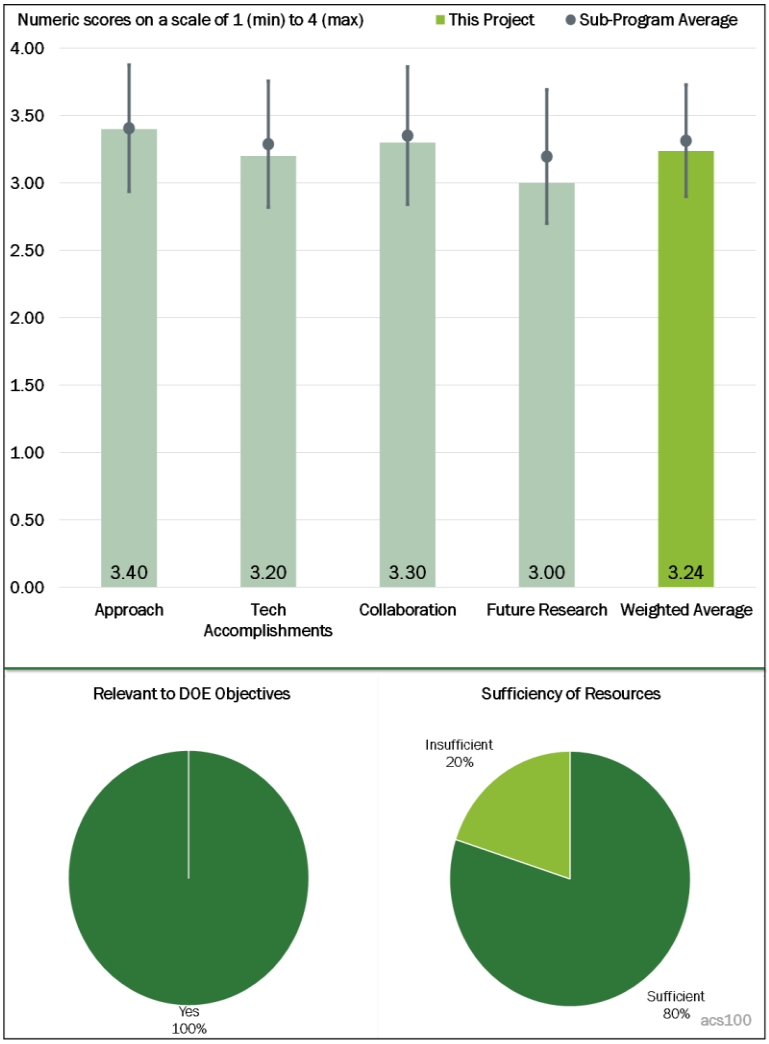

Figure 1-23 - Presentation Number: acs100 Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research—SuperTruck II Principal Investigator: Justin Yee (Daimler Trucks North America)

Reviewer 3:
The reviewer suggested that a bit more detail on the approach would have been helpful to understand thoroughly both the overall and the specific powertrain.

Reviewer 4:
The reviewer noted that the switch to a 48V system is crucial to this type of hybrid. The aero system seems to be well developed. However, the reviewer stated disappointment that the start-stop system was not in the primary development pathway. The predictive engine and drive systems seem also to have been removed from the major development pathway. Those plus start-stop have appreciable fuel economy benefit.

Reviewer 5:
The reviewer acknowledged that the technical approach described in Slide 4 of the vehicle side contains all of the key technological elements required for this program. Specific improvement targets on each technology look good. Similarly, the approach taken on the engine side (Slide 11) is also good and clear. However, the reviewer observed that there is still a big gap to achieve the program goal as indicated in the gray bar of this slide, which cast the doubts of whether this program can achieve the 55% BTE goal.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that the team has made very good progress on initial hurdles in defining various elements.

Reviewer 2:
The reviewer commented that good accomplishments were presented in the multiple areas of aero, powertrain, engine, energy management, and controls.

Reviewer 3:
The reviewer noted that the team seems on track to deliver to the technical requirements making system level decisions. The balancing act of eco-roll versus mild hybrid, and hill climbing versus flat land efficiency are all good examples.

Reviewer 4:
The reviewer observed that this project has focused on the low hanging fruit for improving fuel economy. However, there is a next level that may be needed to reach the goals. The smaller percent improvements like these two maybe required to make the target. The reviewer suspected that there is more to recover using vehicle controls than the 1% estimate shown in Figure 4. Also, the 6% shown from the powertrain might be a little low.

Reviewer 5:
The reviewer said that good progress has been made on aero (Slide 6) and tires (Slide 7). However, it is not clear whether single wide base tires would be used, although the picture clearly shows dual tires. The reviewer questioned why the single wide based tire would be abandoned in such an early stage, where there is clear advantage of single wide base tires over dual tires. The reviewer further commented that technical progress on powertrain seems to be too simplified with only one slide (Slide 12). It could add more details to enhance the program values for reviewers to appreciate. It is not clear what kinds of twin-turbochargers would be used, whether variable-geometry turbocharger or waste-gated. Such vague description would not help the program clarity.

The reviewer was not sure how the proposed predictive engine control (Slide 14) would be able to be implemented into the engine control unit (ECU) with such complicated modeling structure, evidenced by the air path model of this slide. In addition, the fidelity of this type of model in predicting transient behaviors is in question. This modeling approach would be even more in question when the model includes an aftertreatment system, which would make the memory of ECU even more challenging. Furthermore, the reviewer questioned how the authors could credit the SuperTruck I (ST1)'s model-based control algorithms to this program, because this approach used in SuperTruck II (ST2) is totally different from ST1's, where the latter largely relies on a neural network model based on Atkinson's unique approach. Finally, this seems to be not practical even for consideration of use in production. As a result, this reviewer viewed the progress on predictive engine control as backward compared to ST1.

The reviewer remarked that one of the big concerns of the progress would be waste heat recovery (WHR), which is highlighted in Slide 16. Without WHR, it would be hardly believed that this program can achieve the program 55% BTE goal. The progress on WHR should be the key reporting topic in the next review. In Slide 2, the reviewer was confused about why the author added progress on "Basic aero shape development is done…" to the Barriers, which has nothing to do with barriers. Overall, this reviewer concluded that this presentation seems not to be well-reviewed and written, specifically on the powertrain side.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that partner integration in the project appears to be exceptional.

Reviewer 2:
The reviewer noted that this is a well-structured team with many, well qualified partners. Their collaboration and contributions seem significant, and it is good to see not just suppliers as collaborators.

Reviewer 3:
The reviewer offered that this was a strong team, utilizing expertise throughout. The reviewer suggested that all of these ST projects should engage end-users more in their work. The reviewer said that this project had too much reliance on in-house customer knowledge.

Reviewer 4:
The reviewer affirmed that project collaboration and coordination seem to be good, including all major partners (Slide 19).

Reviewer 5:
The reviewer noted that the team did not adequately define the roles of each of 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 stated that the work plan going forward is well defined.

Reviewer 2:
The reviewer observed that this team has a solid plan for the rest of the program. The reviewer would like to see some more details on how the systems are being evaluated for total cost of end user ownership.

Reviewer 3:
The reviewer noted that going after the tasks in the stretch goals may be required to make the goal.

Reviewer 4:
The reviewer indicated that the proposed future research shown in Slide 17 seems to be mainly for the vehicle. It would be clearer if a similar slide would be developed for the engine.

Reviewer 5:
The reviewer said that not much detail was provided on future research. The WHR discussion during the question and answer was helpful, but this is aimed at the stretch goal.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that the project has excellent alignment with overall DOE objectives.

Reviewer 2:
The reviewer noted that Class 8 over-the-road tractors consume 80% of truck fuel burned. The SuperTruck project is delivering.

Reviewer 3:
The reviewer reported that all of the improvements shown in this project are directly relevant to getting a more fuel-efficient truck onto the highway.

Reviewer 4:
The reviewer noted that the project aims to improve the engine efficiency and overall freight efficiency for reduction of fuel consumption, which aligns with DOE objectives.

Reviewer 5:
The reviewer noted that this program should be able to substantially reduce fuel consumption, thus supporting the overall DOE objectives

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

Reviewer 1:
The reviewer observed excellent resources and facilities at the partner laboratories.

Reviewer 2:
The reviewer noted that the resources appear to be adequate for the program to meet it is objectives.

Reviewer 3:
The reviewer reported that resources were sufficient.

Reviewer 4:
The reviewer believed more manpower needs to be placed on the stretch technologies.

Reviewer 5:
The reviewer commented that it may be sufficient on the total vehicle to achieve the vehicle related goals, but it would be in question whether the team has enough resources and funding on the engine side to achieve 55% BTE goal because of lack of progress on WHR.

Presentation Number: acs101
Presentation Title: Volvo SuperTruck II: Pathway to Cost-Effective Commercialized Freight Efficiency
Principal Investigator: Pascal Amar (Volvo Trucks North America)

Presenter
Pascal Amar, Volvo Trucks North America

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 and well-planned.

Reviewer 1:
This reviewer appreciated the collection of fleet info and was especially impressed with the collection of off-highway use, which is suspected to be the main fuel usage. The lightweighting approach with durability testing is appealing. The reviewer highlighted that including overnight stays in the driving profile is great. For as long as this reviewer has been reviewing SuperTruck projects, this person has seen how much the aerodynamics has reached the highway. There is quite a lot.

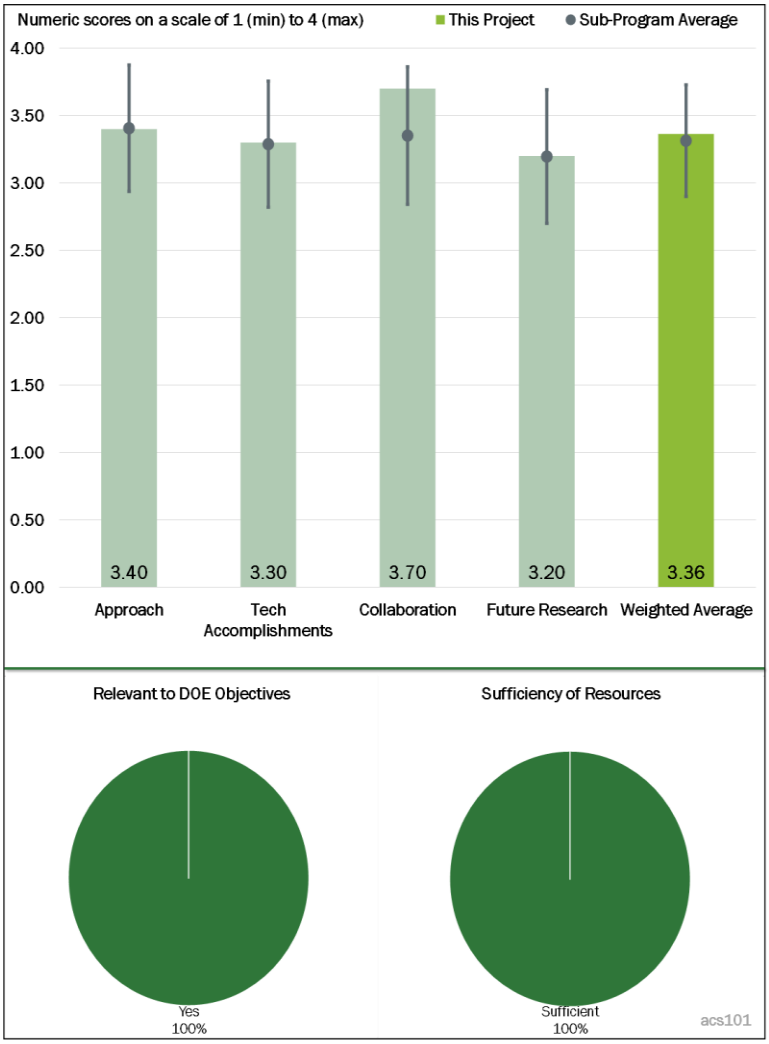

Figure 1-24 - Presentation Number: acs101 Presentation Title: Volvo SuperTruck II: Pathway to Cost-Effective Commercialized Freight Efficiency Principal Investigator: Pascal Amar (Volvo Trucks North America)

Reviewer 2:
The reviewer noted this to be an excellent project looking at all salient aspects.

Reviewer 3:
The reviewer stated that this project has a solid approach. The PI referenced ST1 oftentimes proving that the author had ideas in that program without time or budget to enact them and are now doing so with ST2. This project is approaching commercial viability well. When the reviewer asked the PI how this was being done, the PI answered with "Creating models for TCO decisions by technology." The reviewer remarked that this was well done and will look to see these next year.

Reviewer 4:
The reviewer observed that for the approach to vehicle configuration, the seemingly large effort going into data collection to map out the fleet driving cycle was a little surprising. The reviewer would have assumed that this was information that was already known to a major truck manufacturer. Perhaps something different was missing about this particular data collection, such as hotel loads. The rest of the approach is sound, except for

the continuation of the split-cycle engine. The reviewer was not sure what has been driving the continued interest in this technology.

Reviewer 5:
The reviewer commented that the approach for the vehicle mentioned in Slide 8 is too simplified, which only talks about fleet duty cycle creation. The reviewer mentioned that the technology road map includes many technologies. On the engine side, the reviewer was not sure how valuable the dual compression/expansion engine is. Even if it would work, which would be still a big "if," the reviewer questioned how this could be fit into the vehicle. Also, it seems that the concept of this engine could increase engine weight significantly according to the figure in Slide 23, which may eat up other benefits. The reviewer concluded that no plan is demonstrated that this engine can have a chance to be realized in the vehicle.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that the aggressive approach to powertrain weight reduction is very impressive. The lessons learned here can be propagated forward in many applications. This work shows that there is significant fuel savings in "look ahead" driving strategies. The reviewer observed that the hotel cycles especially were thought through.

Reviewer 2:
The reviewer noted good progress on the tires, lightweighting, and aero for the truck are evident. Combustion, heat loss, and electrification all showed good accomplishments on the powertrain.

Reviewer 3:
The reviewer said that the project is making good progress on some very difficult key decisions and is using field data well.

Reviewer 4:
The reviewer remarked that the project is making very good progress with the project 35% complete. However, the project lead admits that the 55% BTE will not be achieved. The combustion work has led to unexpected/counterintuitive findings; however, these were not specified. The author mentioned that an empirical approach may be more useful than the simulations.

Reviewer 5:
The reviewer commented that no intermediate BTE progress is reported. Most of the work accomplished today was only planning and concept design. To a minimum, the progress has been specifically on the simulation side. On the advanced engine, it should be made in terms of BTE, if no testing is available at this time. The reviewer observed that no actual value can be appreciated with this new engine concept if it would not be fitted into a vehicle. If this is so, the reviewer suggested that resources are wasted on this engine.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer affirmed that project lead (Volvo) has been very proactive in defining and involving partners. For example, the weight reduction measures identified by Penn State collaborators are noteworthy.

Reviewer 2:
The reviewer stated that collaboration and coordination seem to be excellent, which the presentation shows in Slide 3.

Reviewer 3:
The reviewer noted very good collaborations shown on this project, and nicely summarized on Slide 3.

Reviewer 4:
The reviewer highlighted very strong assets of this team. The PI openly mentioned that the team has a unique, strong proposal from Bergstrom that they are very excited about. This is an example of collaboration versus "not invented here." The reviewer suggested that this team may have more of these examples.

Reviewer 5:
The reviewer reported that clearly there are a good range of partners. It was not clear to the reviewer which ones made major contributions and which were less impactful.

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 research is to keep on going and totally agrees with this.

Reviewer 2:
The reviewer noted a very strong plan exists for the rest of the project. The reviewer suggested planning on incorporating some cab changes.

Reviewer 3:
The reviewer commented on the aftertreatment system, describing that the use of a close-coupled SCR upstream of the filter may lead to the undesired consequence that passive regeneration cannot be accomplished. This can decrease efficiency by 1%. The reviewer requested that the project team please comment on this decision.

Reviewer 4:
The reviewer noted that not much time was spent on the future plans, so this was difficult to evaluate.

Reviewer 5:
The reviewer said that it would be much clearer if the presentation would be written in such a way that one or two separate slides would be dedicated to proposed future research, although some of the future plans can be seen in some of the individual slides.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted clear and obvious alignment with DOE objectives.

Reviewer 2:
The reviewer highlighted that especially relevant are the aggressive weight reduction technologies and the on-the-road adjustments of engine and driver strategies.

Reviewer 3:
The reviewer said that the project seeks to improve freight efficiency and engine efficiency, consistent with DOE goals.

Reviewer 4:
The reviewer remarked that Class 8 burns a ton of fuel and this team is committed to not only showing a ST2 with much better freight efficiency but spinning off ideas into production as quickly as possible.

Reviewer 5:
The reviewer stated that this program, if delivering, would definitely help the nation to reduce fuel 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 noted that resources were absolutely sufficient.

Reviewer 2:
The reviewer asserted that the team seems to be doing well with the present level of funding.

Reviewer 3:
The reviewer commented that the resources look to be in line with the work completed and proposed.

Reviewer 4:
The reviewer reported that the resources are sufficient.

Reviewer 5:
The reviewer commented that, with the vast past experience obtained from ST1, the project should have sufficient funding to complete the program

Presentation Number: acs102
Presentation Title: Cummins-Peterbilt SuperTruck II
Principal Investigator: Michael Ruth (Cummins-Peterbilt)

Presenter
Michael Ruth, Cummins-Peterbilt

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 and well-planned.

Reviewer 1:
The reviewer could see no way to suggest improvements. The active yaw control is unique and makes great sense and, at present, is unique for this application. It also may be a safety feature in helping make the tractor-trailer system less susceptible to overturning during a catastrophic event. The reviewer observed that the other accomplishments are first-class also.

Reviewer 2:
The reviewer commented that the level of system integration across the entire vehicle is very impressive and well thought-out, down to addressing components which usually would be ignored. The project appears well-designed to address both the freight efficiency and engine efficiency goals.

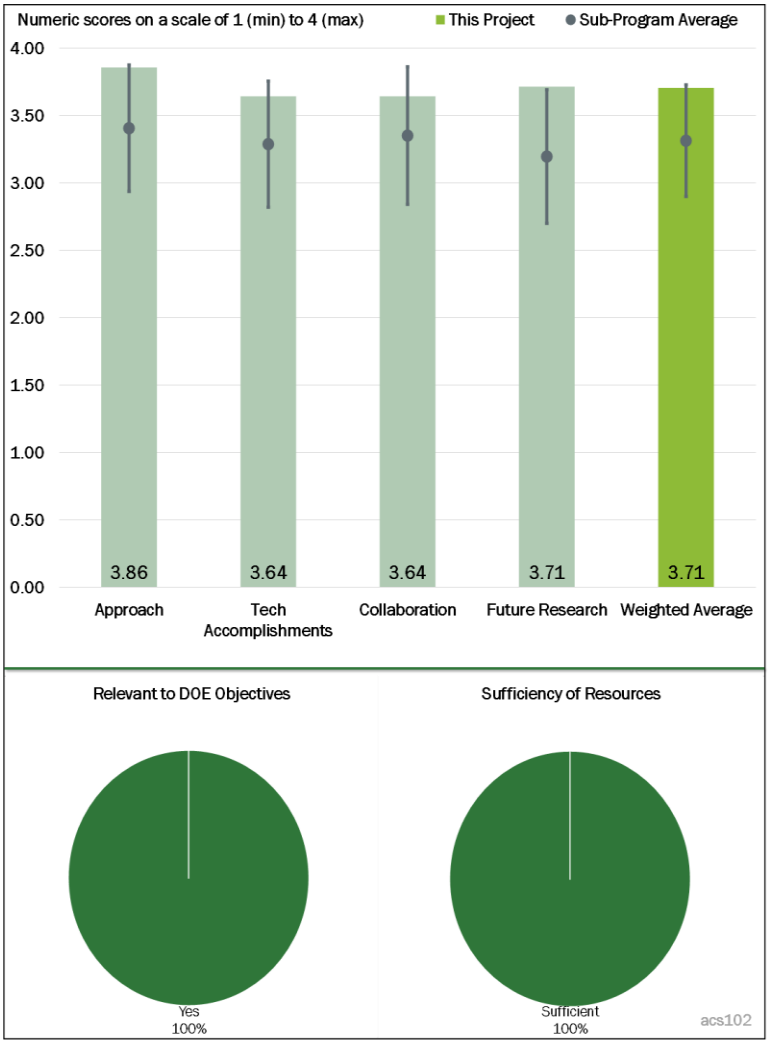

Figure 1-25 - Presentation Number: acs102 Presentation Title: Cummins-Peterbilt SuperTruck II Principal Investigator: Michael Ruth (Cummins-Peterbilt)

Reviewer 3:
The reviewer stated that this was an outstanding project on all fronts.

Reviewer 4:
The reviewer noted that this is a very well thought-out set of technologies done by people who know the business and do good analysis and testing.

Reviewer 5:
The reviewer acknowledged an excellent approach on the trailer, tires, and aero. The Cummins Energy Recovery Drive with the waste head recovery integrated provides a novel packaging approach to the program.

Reviewer 6:
The reviewer remarked that the project had a very strong approach. The ST2 teams benefit in efficiency on these programs having completed ST1. This refines the approach and gets more done for the money, which is impressive.

Reviewer 7:
The reviewer offered that this is an outstanding program with very aggressive goals, but with a comprehensive plan to back up the claims. A complete new engine to support the program is a big plus together with their previous success from the ST 1 program. The reviewer noted that this was very well done, but it still remains to be seen whether it can really deliver.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that this ST2 project is clearly best of the best. All the other projects are focusing on individual parts of technology. Basically, this project has them all.

Reviewer 2:
The reviewer indicated that the quoted achievements to date are in line with what would be expected at this point in the program, and are well documented to demonstrate the progress.

Reviewer 3:
The reviewer noted progress has already been made on efficiency targets.

Reviewer 4:
The reviewer observed that this is impressive work. Both experimental and analytical methods are used and are well integrated. The reviewer concluded that very nice progress is reported.

Reviewer 5:
The reviewer affirmed that great progress is made in all areas of the engine and vehicle.

Reviewer 6:
The reviewer stated that it is an impressive design on this new engine/powertrain platform (Slide 11 and Slide 12). Excellent progress has been made (shown in Slide 13), but there is still some distance to go in meeting the 50% goal, but it should be on the way. The disengage-able tandem axle made this program more practical to deliver overall better performance even with 0.4% fuel economy improvement. The reviewer suggested that Slide 10 (ST 2 Target) as presented, is confusing. More description on this figure would be helpful. In addition, it would be more helpful if the path shown in Slide 21 includes clearer indication of the scale of BTE improvement.

The reviewer said that the progress on the vehicle side is also impressive. Weight reduction is aggressive (Slide 35). Although good progress has been made on the tire side, it is not clear why single wide base tire was not selected for this program, which does not make common sense. The reviewer offered that explaining this decision between single and dual tires would be helpful.

Reviewer 7:
The reviewer was a bit unsure about this project. It seemed to the reviewer that more evidence of progress on technical accomplishments could have been added here. It seems like there was a lot of effort on weight reduction and with only a few fleets able to really add payload. This may not be best in the long term.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the team has organized an impressive set of partners and suppliers. All the important aspects of the program seem to have been worked on by experts who are doing their part, with effective coordination and collaboration.

Reviewer 2:
The reviewer noted that clearly the Cummins-Peterbilt collaboration is a partnership. Bridgestone has contributed well. Walmart is a great contribution to this program. It puts a real-world aspect into the driving profiles. The reviewer concluded that Eaton is good on transmissions.

Reviewer 3:
The reviewer observed involvement of a large and comprehensive group of collaborators.

Reviewer 4:
The reviewer remarked that Slide 5 shows strong collaborations with various partners.

Reviewer 5:
The reviewer acknowledges a great list of collaborators; however, it would be helpful to point out who is a supplier/vendor and who is a participating partner. Collaborator roles for some were pointed out in the technical accomplishments throughout the presentation, but only a handful of them were mentioned. The reviewer questioned what the rest are contributing.

Reviewer 6:
The reviewer commented that results from some of the partners in the team were called out and appears to be well integrated into the overall program plan. There were many more partners listed who did not have any documented activity in the presentation. It was unclear to the reviewer if this is because their contribution is called for at a different time or if the author was just not able to fit them into the presentation. It would be good to have a sense of what all the partners were doing given the huge list of them.

Reviewer 7:
The reviewer would like to see more work with end-user fleets. The reviewer suggested some sort of annual or biannual ST2 customer focus group. These teams are relying too much on in-house knowledge of customers' expectations.

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 plan presented seems to be very well-thought through and will evaluate a very wide range of technologies, with an effective plan to develop the necessary data and downselect the right set of components. This is the way it should be done.

Reviewer 2:
The reviewer noted that a great pathway was laid out for reaching the program goals.

Reviewer 3:
The reviewer observed that finishing the project in all its aspects is clearly a great forward plan.

Reviewer 4:
The reviewer affirmed that there is a strong plan in place to finish this project.

Reviewer 5:
The reviewer stated that it does appear that the plans for future work are well-constructed to achieve the ST2 goals. It would be good to see some kind of efficiency waterfall plot to get a sense of the demands on each development in the plan and to see where uncertainty in the final performance would impact the path to the 55% BTE goal.

Reviewer 6:
The reviewer said that the plan forward was fine.

Reviewer 7:
The reviewer highlighted that the proposed future research that includes cost makes this program more practical. A few technologies on the powertrain side, including low-pressure EGR and mild hybrid system, are appropriate. The reviewer questioned why there is not anything related to combustion, WHR, and other technologies. One of the drawbacks on this presentation is that there is nothing mentioned on the vehicle side for the proposed future research.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that this project is directly in line with the overall DOE objectives to increase energy efficiency and reduce petroleum consumption. It also seems likely to impact real-world fuel use based on the experience from ST1 and the technology transfer from the DOE program to production trucks.

Reviewer 2:
The reviewer observed that ST2 seems to be critical, and very relevant, to the DOE mission.

Reviewer 3:
The reviewer stated that this is a critical project to fulfill DOE objectives.

Reviewer 4:
The reviewer said that Cummins has already pushed some of the ST1 developments into production. If this continues then the relevance is obvious.

Reviewer 5:
The reviewer affirmed that the goals of improved engine efficiency and freight efficiency are well aligned with the DOE objectives.

Reviewer 6:
The reviewer remarked that for the United States to decrease fuel use and carbon dramatically, over-the-road tractors need to be addressed, and this project does that.

Reviewer 7:
The reviewer indicated that this program would certainly help to reduce imports and improve energy security.

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

Reviewer 1:
The reviewer offered that there appears to be plenty of resources to perform the planned work towards the project milestones and end goals.

Reviewer 2:
The reviewer observed excellent facilities and resources.

Reviewer 3:
The reviewer commented that the resources seem to be both necessary and sufficient for a large program such as this one.

Reviewer 4:
The reviewer noted that when the components developed in a project are clearly market ready, then the funding is sufficient. The reviewer suspected that the partners long-term are getting much more out of the project than their individual contributions.

Reviewer 5:
The reviewer remarked that resources look appropriate for the work accomplished and proposed.

Reviewer 6:
The reviewer indicated that the resources appear sufficient.

Reviewer 7:
The reviewer said that the team's past vast experience should help the program to complete in time and in the given resource.

Presentation Number: acs103
Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck
Principal Investigator: Russell Zukouski (Navistar)

Presenter
Russell Zukouski, Navistar

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 and well-planned.

Reviewer 1:
The reviewer commented that the project is well-configured to address the technical challenges associated with achieving the freight and engine efficiency improvements of the ST2 program.

Reviewer 2:
The reviewer noted that the project was overall well-planned with a clear approach to achieving goals for engine and vehicle. As a modest weakness, the GCI side project seems just that, a project on the side, maybe as a contingency in gasoline in case the core diesel plus aftertreatment path has an issue.

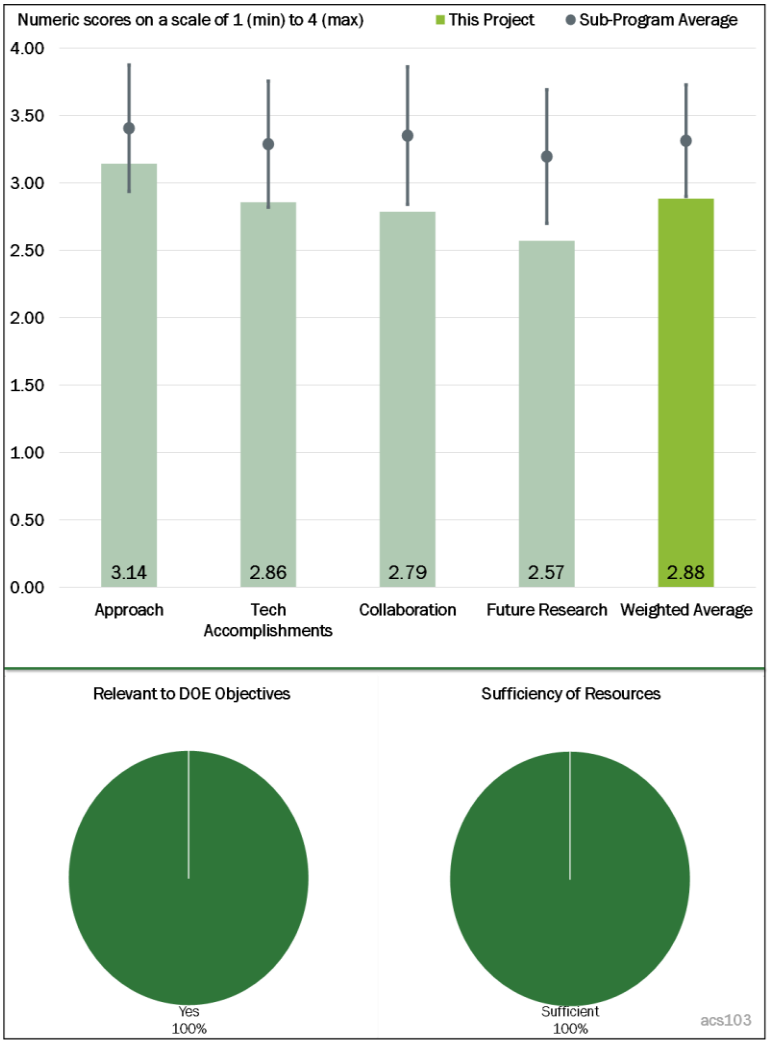

Figure 1-26 - Presentation Number: acs103 Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck Principal Investigator: Russell Zukouski (Navistar)

Reviewer 3:
The reviewer remarked that the project generally had a good approach. The reviewer was not clear how the ANL GCI work fits into SuperTruck.

Reviewer 4:
The reviewer indicated that the approach is strong for success. The reviewer would like to see more work/engagement with end-user fleets. The project is currently relying too much on in-house expertise.

Reviewer 5:
The reviewer stated that the thoroughness evident in the other ST2 projects was not as apparent with this project.

Reviewer 6:
The reviewer observed that this is mostly a planning project that is well behind all the other programs. There is no indication of what electrification system will be used. There is no evidence that the compression ignition technology will work. The reviewer believed that a report from ANL would have been very helpful. The reviewer commented that the project had nice work on the drivetrain axle. The aerodynamics work is pretty consistent with all the other competitors. It probably means that the solutions are obvious. The reviewer could not tell what the exhaust temperatures are predicted to be. Gasoline exhaust is typically higher than diesel. An electrically heated catalyst might be energy efficient.

Reviewer 7:
The reviewer observed that the technical approach shown in Slide 5 included all key technology components except tires. It is hard to understand why tires would not be part of the key technology package. In addition, the reviewer proffered that it would be helpful to be more specific in terms of relative scale. Just from this figure (Slide 5), it seems that WHR is so critical, taking more than 50% contributions to achieve 55% BTE, which makes the program too risky if WHR cannot achieve the target goal.

The reviewer further commented that with limited resources, it is not clear whether a second engine with GCI concept would be a smart choice to study. Because there would be only one engine that can be installed in the vehicle, it is a high risk to divert funding on a high-risk engine, where the limitation on this engine would be high loads for on-highway application.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed that the team has made solid progress on the key engine and vehicle subsystems. The engine subsystems include air handling, fueling, WHR, etc. Vehicle tractor-trailer coupling to enhance the integrated aero package is noted. On the vehicle system, electrification is shown as having a 2% benefit. Hybridization is noted as “double-digit” impact. The reviewer recommended that a more precise estimate for certain drive cycles would have been welcomed, or else discussion why an estimate was not ready.

Reviewer 2:
The reviewer stated that the project had good progress. The reviewer would like to see more evidence of using commercialization criteria on decision making.

Reviewer 3:
The reviewer commented that the progress seems okay. Most of the stated activity appeared to have some forward motion but most tasks also seemed to have not fully achieved the goal of each task. While it is still reasonably early in the project, it would be nice to see how the results to date impact the team’s assessment of their progress towards the final program goals.

Reviewer 4:
The reviewer said that the author reported many progresses, but they are largely analytical. The author reported no progress on the tire side, which should be one of the critical parts of this program. This is one of the biggest drawbacks of this program. The reviewer remarked that it is too vague to mention that “a compound system has been identified” of WHR in Slide 8. The reviewer questioned what that was.

The reviewer also commented that it is not clear how this GCI engine has more potential to achieve 55% BTE goal than the conventional engine, according to Slide 9. Even if it does, the reviewer wondered if there is any possibility for vehicle demonstration. Again, using two engines for this program would be too risky and may end up as a total waste considering the limited funding.

Reviewer 5:
The reviewer warned that the accomplishments are lagging in this project. There is much work to be done.

Reviewer 6:
The reviewer noted that there was not much real data presented.

Reviewer 7:
The reviewer said that only 20% completion seems to be significantly less than the other ST2 projects.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the project has strong teamwork. The reviewer would like to see end users more apparent and involved. The reviewer proposed an ST2 annual or biannual focus group meeting.

Reviewer 2:
The reviewer noted that the project teaming arrangement looks good for achieving the goals, but it is not clear at all from the presentation how much the team is working with Daimler and how much is its own.

Reviewer 3:
The reviewer indicated that the team members mostly appear to have direct input to the final goals and vehicle prototype. The exception may be the ANL engine project, where it is unclear what outcomes or data will be used in the final vehicle or 55% engine.

Reviewer 4:
The reviewer noted that there are major expectations for the partners to make this project successful; however, there were no reports from the partners on the progress of the partners.

Reviewer 5:
The reviewer said that there was good collaboration with suppliers. However, the reviewer did not see a trailer maker involved in the major program work. Integration of cab, engine, and trailer seems to be critical in these ST2 projects.

Reviewer 6:
The reviewer said that Slide 3 well defines the role of each team member to play, but having no tire partner is disappointing.

Reviewer 7:
The reviewer observed that the lack of a fleet partner on the team may be an issue.

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 plan to deliver seems strong.

Reviewer 2:
The reviewer asserted that the presentation lacked clarity on future research, with next steps being spread throughout many pages. Those various items were okay when found. The future of the all-important WHR system needed more discussion.

Reviewer 3:
Generally, the reviewer described the plan as okay. However, the reviewer would like to see the team clarify whether and how the ANL GCI work fits, and how selection will be made for the final project. As the reviewer understands it, the program metrics are based on highway 18-wheeler operation. If GCI is used in a multimode system, the reviewer questioned how often it will be used. The reviewer wondered if there is a plan to develop mode switching and real-time optimization. Regarding the effects of fuel, the reviewer questioned if a dual-fuel system is required and if so, if it is customer acceptable and cost effective. In the reviewer's experience, many truck stops have diesel and gasoline at completely different fuel islands and that might be objectionable to the drivers if both are needed.

Reviewer 4:
The reviewer noted that the future research is all with the partners. No real information was presented.

Reviewer 5:
The reviewer remarked that there really was not any discussion of the future research or how the results to date are changing the plans for the next FY of the program.

Reviewer 6:
The reviewer observed that no details were provided.

Reviewer 7:
The proposed future plan is too simplified, which is shown in Slide 17.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that the project pushes the state of the art forward, and supports DOE's mission in energy efficiency and competitiveness in vehicles.

Reviewer 2:
The reviewer offered that the project is aligned well with DOE objectives.

Reviewer 3:
The reviewer commented that ST2 seems to be very central to the DOE mission.

Reviewer 4:
The reviewer said that this program will significantly reduce fuel consumption, which should support the overall DOE objectives.

Reviewer 5:
The reviewer noted that fuel use is high for Class 8 over-the-road vehicles and this segment must be addressed aggressively.

Reviewer 6:
The reviewer remarked that if successful, the project will achieve DOE goals of reducing petroleum consumption and increasing transportation efficiency.

Reviewer 7:
The reviewer noted that if successful it will move some of the Class 8 fuel consumption from diesel to gasoline. That is a mixed blessing. The value of that will depend on the most efficient hydrocarbon mix from the refiners.

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

Reviewer 1:
The reviewer acknowledged that ST2 projects are quite large and long-duration. The resources seem adequate and appropriate.

Reviewer 2:
The reviewer said that the resources appear sufficient.

Reviewer 3:
The reviewer reported that there appears to be adequate funds for a successful program. It is a bit hard to track if the work to date aligns well with the funds expended and the glide slope towards the project end goals.

Reviewer 4:
The reviewer stated that, considering the breadth of the development of technologies and the final field tests, the resources are just adequate and only with the cost share.

Reviewer 5:
The reviewer had no idea if the partners are cash strapped or not.

Reviewer 6:
The reviewer noted that it was unclear what facilities are available for emission control systems.

Reviewer 7:
The reviewer suggested that the program should focus on one main engine platform. Diverting the funding on two engines would risk the program funding sufficiency.

Presentation Number: acs116
Presentation Title: Advanced Non-Tread Materials for Fuel-Efficient Tires
Principal Investigator: Lucas Dos Santos Freire (PPG Industries)

Presenter
Lucas Dos Santos Freire, PPG Industries

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 and well-planned.

Reviewer 1:
The reviewer remarked that tires provide a lot of payback in terms of fuel efficiency. This is a viable approach.

Reviewer 2:
The reviewer commented that a good approach was seen. Groups with solid knowledge have defined an important area of work and opportunity.

Reviewer 3:
The presented approach to this project looked sound and thorough.

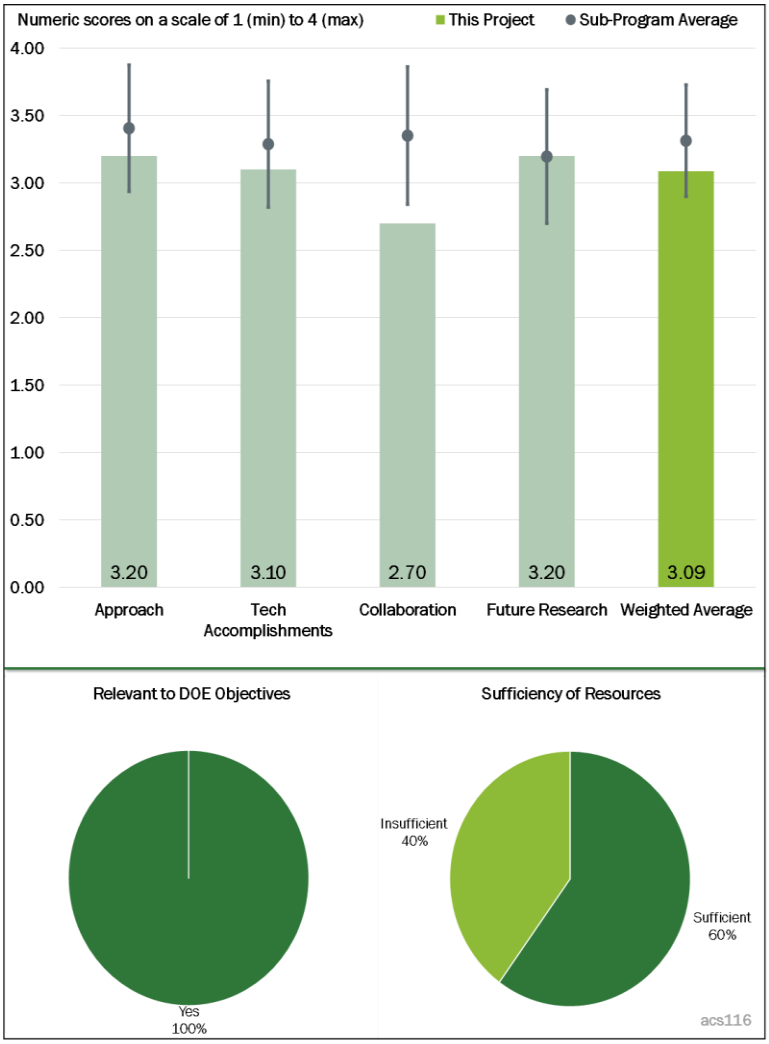

Figure 1-27 - Presentation Number: acs116 Presentation Title: Advanced Non-Tread Materials for Fuel-Efficient Tires Principal Investigator: Lucas Dos Santos Freire (PPG Industries)

Reviewer 4:
The reviewer indicated that while there is merit to giving attention to sidewall materials and not just tread materials, doing so somewhat independently instead of as a system, and proceeding without integrated involvement of a tire manufacturer, appears risky and suboptimal.

Reviewer 5:
The reviewer stated that the approach is systematic, but the underlying reasons for selecting the approximately 10 different fillers were not articulated. This comes across as being somewhat Edisonian. Also, the different tests were not defined in terms of why these collectively comprise the criteria for optimizing the compound. The reviewer suggested that a better case could have been made on why the tests selected are relevant. If these are well-accepted by the industry, then say so. The reviewer concluded that the presentation was overall uninspiring.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed that the team has made excellent progress on reducing the tan delta of materials along with researching other critical properties. The metric of tan delta is more subtle than the coefficient of rolling resistance (Crr), the later used much in describing the characteristics of complete tires. The project accomplishments would be clearer if related to Crr.

Reviewer 2:
The reviewer characterized the progress as excellent so far. It will be good to see work with a tire company and a real tire result.

Reviewer 3:
The reviewer noted that it seems that quite a lot has been achieved, but it is difficult for this reviewer to understand the pathway that leads to the end goal.

Reviewer 4:
The reviewer commented that it is not clear from the presentation what the metric for improvement is. Additionally, there is no comparison with present sidewall products. Slide 15 comments on this, but it has very inadequate information.

Reviewer 5:
The reviewer reported that the compound results do not show a sample that meets all four goals (Slide 10), at least before compound adjustment.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that PPG has an excellent partner with Akron Rubber Development Laboratory (ARDL) with a lot of expertise in this industry. The reviewer encouraged the project to consider additional partners, like universities, although the reviewer acknowledged that this project does not have a large budget.

Reviewer 2:
The reviewer really wishes that this work was integrated with the major tire manufacturers. It would help to ensure any major accomplishments would be incorporated into future products.

Reviewer 3:
The reviewer suggested that the project would be stronger if one or more tire companies were fully integrated with the team. The support letters helped to justify a satisfactory score.

Reviewer 4:
The reviewer indicated that the collaboration aspects were not articulated. The ARDL was mentioned but their contribution is unclear to date.

Reviewer 5:
The reviewer said that this project will be better with one or more tire companies in the future.

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 research seems adequate as there is convergence to a final compound.

Reviewer 2:
The reviewer observed that this seems like a good approach, developing the materials with laboratory tests, and eventually building tires for testing.

Reviewer 3:
The reviewer reported that the team has identified the key points for future research. The reports cited that explain the relationship between tan delta and rolling loss coefficient are not really adequate. It may be more straightforward just to add a slide discussing this fundamental visco-elastic characteristic. The reviewer further noted that gaining the interest of a tire company is essential, and this process was not described well.

Reviewer 4:
The reviewer offered that there should be a cost analysis included.

Reviewer 5:
The reviewer asserted that not a lot of detail was presented for future research, nor could it be found in the reviewer only slides. More information would have helped understand how the remaining barriers will be overcome.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that this project addresses the DOE objective to reduce fuel consumption for transportation vehicles. It would be applicable across all vehicle types, so potentially could have a big impact.

Reviewer 2:
The reviewer said that this project was relevant because of focus on fuel economy improvement.

Reviewer 3:
The reviewer commented that improved rolling resistance will improve efficiency and that fits DOE goals.

Reviewer 4:
The reviewer indicated that the tire manufacturers have made great strides in improving the fuel efficiency of the vehicles. The reviewer admitted not being well informed what specifics Bridgestone or Michelin are addressing, so it is not known if this is redundant. The reviewer agreed that sidewalls are a big contributor.

Reviewer 5:
The reviewer asserted that rolling losses are highly relevant to trucks and passenger vehicles. The reviewer recognized that significant progress has been made in last 15 years, but tradeoffs remain with wet traction and wear.

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 PPG is well equipped to carry out the materials evaluations.

Reviewer 2:
The reviewer observed that until the project scales up to prototyping full tires, the resources are reasonable.

Reviewer 3:
The reviewer remarked that, not knowing how much laboratory development and testing costs, it seems like the resources are probably sufficient.

Reviewer 4:
The reviewer stated that it is not clear from the lack of a cost analysis and the lack of a large-scale tire manufacturer whether this project needs additional funds to get to implementation. This project has very limited value if there is no clear plan to reach implementation.

Reviewer 5:
The reviewer commented that the budget on this project seems quite low for the amount of effort and the barriers it is trying to overcome.

Presentation Number: acs118
Presentation Title: Advanced Emission Control for High-Efficiency Engines
Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Presenter
Yong Wang, Pacific Northwest 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 and well-planned.

Reviewer 1:
The reviewer appreciated that the project team was willing to adjust the scope based on reviewer feedback. It looks like catalyst characterization work at PNNL is the most prominent part of the work.

Reviewer 2:
The reviewer stated that it appears that the PNNL group has reduced their scope to better align resources with desired, emerging catalyst technologies. This is more desirable from a reviewer's point of view. This year's update reinforces this approach on two very important forward-looking technologies, which are PNAs and compressed natural gas (CNG) catalysts. With respect to PNAs, continuing their effort to understand the uptake and release mechanisms to optimize the material is important. New insight is also gained from their work with different pore size and form of support. The reviewer further indicated that including work to understand deactivation mechanisms is required to determine the limitations of new materials at an early stage so that there is time to redevelop a technology pathway. Regarding CNG catalysts, although this is addressing the administration's interest in CNG vehicles, the reviewer asserted that most of the OEM community is not in agreement and is not dedicating resources to this area of research.

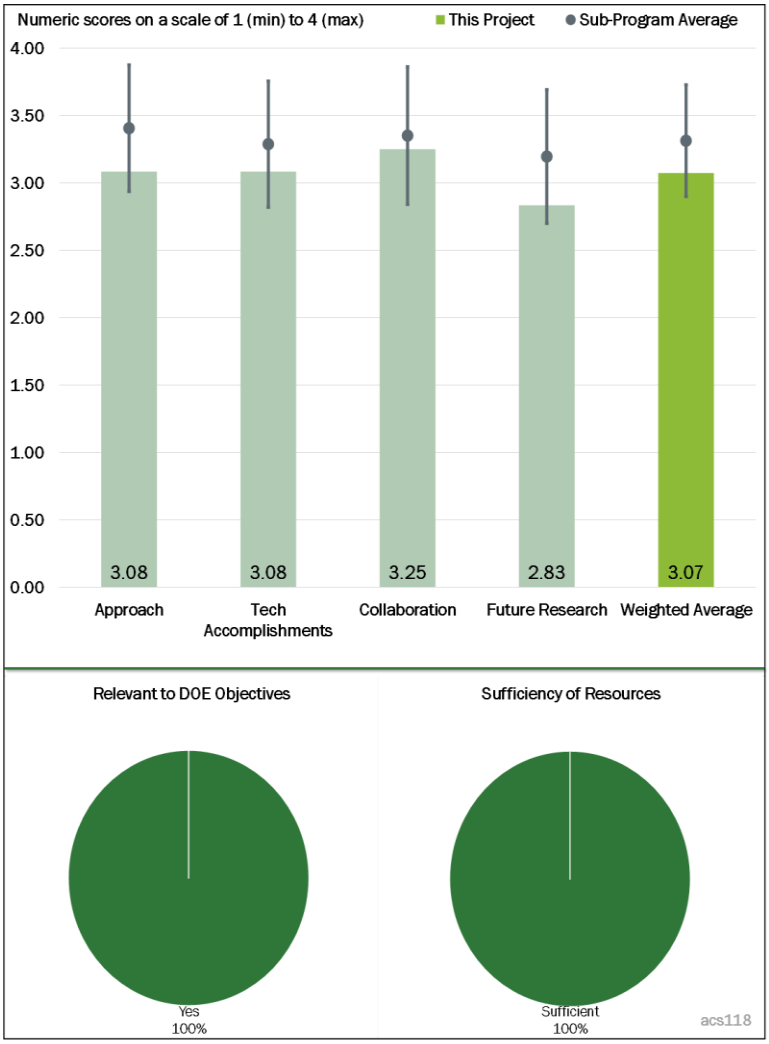

Figure 1-28 - Presentation Number: acs118 Presentation Title: Advanced Emission Control for High-Efficiency Engines Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Reviewer 3:
The reviewer noted that this project has good work. It focuses heavily on the fundamentals, and has looked effectively into aging and palladium dispersion impacts, amongst others. It is nevertheless concerning to the reviewer to see that other fundamental considerations such as impact of HC (or S) are considered "future work" on the 9th year of this study. Instead it is something qualifying that should have been instead in the initial blueprint. The reviewer questioned what is meant by "Study the effect of other gaseous exhaust emission component gases on the performance of PNAs" (stated in Future Work). Specific gaseous species should be

further specified, and the reviewer suggested that more specifics are heavily warranted, especially given that there is only 1 year left to the termination of the project. Despite its beauty, the reviewer stated that the work appears to be harmed by two things (i.e., suboptimal priorities and lack of specifics).

Reviewer 4:

The reviewer observed that detailed characterization using Fourier transform infrared (FTIR), extended X-ray absorption fine structure (EXAFS) and X-ray absorption near edge structure successfully revealed the nature of Pd/zeolite catalysts and the mechanisms involved in NO_x storage in zeolite-based PNAs. However, one critical issue associated with current PNAs is premature release of stored NO_x before reaching the light-off temperatures of SCR catalysts. This issue becomes even more serious after aging. Thus, the reviewer noted that it seems desirable to focus on release characteristics (rather than storage phase as in the past) to determine the controlling factors for the release of storage NO_x from current PNAs and what can be done to modify/improve the release properties, especially after aging.

Regarding the modes of catalyst aging, the reviewer highlighted that a brief exposure to fuel-rich gaseous streams has been observed to be particularly detrimental, and thus is worth considering (in addition to usual HTA) for catalyst aging studies.

The reviewer believed that the reported effects of varying the silicon/aluminum (Si/Al) ratio on Pd dispersion and NO_x storage capacity are interesting observations, but may have limited practical significance/value because zeolites with high Si/Al ratios are generally favored for automotive applications. This is because of their better hydrothermal stability and their effectiveness at mitigating the H_2O inhibition of NO_x storage behavior.

The reviewer observed that this project proposed to investigate both PNAs and methane (CH_4) oxidation catalysts, but there seems to be no obvious synergy between them (although there are literature reports that zeolite-based Pd can be a promising CH_4 oxidation catalyst).

Reviewer 5:

The reviewer noted that vehicular catalysts face extremely harsh conditions, including high temperatures, significant water content in the exhaust flow, S and other poisons in the gas flow, and have a requirement for very long durability at these conditions. A minimum pretreatment for a possible automotive catalyst is 10 hours with steam at 700°C -800°C. This causes severe loss in dispersion, typically a loss of about 90%. The loss over 10 hours is effectively exponential. That loss of dispersion indicates a change in morphology into a phase, which has sufficient stability to retain its activity through the government mandated mileage.

The reviewer further highlighted that the 300°C calcination used in the work up to now is not sufficient to cause this possible morphology change. Suppliers typically do not bother to investigate any new material until it has gone through this stringent aging. Since, in general, the pretreatment of each of the samples is not provided, it is difficult to know if the catalytic material has been sufficiently pretreated to indicate whether it is interesting. The reviewer said that Slides 7, 8, 13, and 14 are good, but questioned if Slides 9, 10, and 11 are fresh only. The reviewer was not certain what the x-axis is on Slide 12.

Reviewer 6:

The reviewer said that feedback from last year suggested a change in the approach, which has been mostly met. Dropping the PM work to focus on PNAs makes sense due to the needs of industry. However, the reviewer suggested that the team focus on aging and poisoning, and while there has been work on HTA, there has been relatively little work on the poisoning. The reviewer concluded that the areas of focus still seem to lack synergy.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that continuing to develop PNA materials that show very good update and retention of NO is very important for addressing the need for LTAT solutions. The reviewer acknowledged very impressive NO_x storage capacity. Continuing to optimize the capacity and release conditions is appropriate. Just as important are their characterization studies to obtain more insight into the material qualities and how to exploit these properties. However, the reviewer highlighted that PNAs must be made robust enough to withstand HTA conditions that will be present in automotive exhaust systems. If they fail at lower temperatures, it is not a viable product. The reviewer concluded that more consideration should be given to this and other deactivation mechanisms.

Reviewer 2:
The reviewer stated that it looks like the project is meeting its milestones as planned, with both the PNA and the CH_4 oxidation catalyst. The reviewer highlighted nice results with the PNA materials characterization, especially as the materials are aged.

The reviewer understands the interest in determining which support properties influence CH_4 oxidation, but the use of SSZ-13 zeolites confounds this work with the PNA work, especially if the team does not expect an SSZ-13 support to be suitable for commercial CH_4 oxidation catalysts.

Reviewer 3:
The reviewer commented that there is certainly progress toward the key goals, although it is not hard to argue progress could have been a bit faster, especially if the team tackled more elementary considerations essential for practical PNA performance in real-world applications.

Reviewer 4:
The reviewer noted that good progress in providing fundamental understanding of NO_x storage in PNAs, but not enough results yet on CH_4 oxidation.

Reviewer 5:
The reviewer could not extract from the presentation the specific history of the sample before it has been tested, and therefore could not decide if the sample has useful information. Certainly, the dealumination is a recognized degradation process and does affect the dispersion, but there is an accompanying sintering that cannot be identified in this presentation. The reviewer observed that Slide 21 is helpful.

Reviewer 6:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that partnering with a supplier that is actively developing this type of PNA is very appropriate. Coupling the supplier's formulation capability with the testing and characterization abilities of PNNL is an excellent combination of resources.

Reviewer 2:
The reviewer stated that it looks like the project benefits from the capabilities and strengths of each project partner on the team.

Reviewer 3:
The reviewer remarked that Cummins and JMI are on-board with PNNL on this project. While it is true that PNNL has unique characterization tools, it is fair to think that the team would have benefited from synergizing additional know-how from having onboard university experts (e.g., University of Michigan, University of Houston, University of Kentucky, or others) familiar with both this technology's fundamentals and the industry needs. The reviewer noted that this would alleviate some of the progress challenges observed, hindering a better, faster progress.

Reviewer 4:
The reviewer observed that, while there is good collaboration between the national laboratory and industry on this project, there seems to be no university involvement in the project. The reviewer would like to see university collaboration included in the project.

Reviewer 5:
The reviewer offered that certainly Cummins and JMI should have similar concerns or they had more information.

Reviewer 6:
Given that this project is in the final stage (ending March 2019), the reviewer did not see evidence of significant participation/contribution by Cummins (or JMI) for possible engine testing. Such collaboration is not included in the Proposed Future Work (Slide 18) either.

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 focus on deactivation mechanisms for future work is very appropriate. However, the reviewer said that an indication of these effects should be performed at an earlier stage so that inappropriate technologies are not advanced in the development process. CNG catalysts are a lower priority and resources should be minimized in favor of PNAs and SCRs.

Reviewer 2:
The reviewer remarked that it looks like the CH_4 oxidation catalyst work on this project is complete. It seems to the reviewer like the PNA durability work overlaps with other DOE-funded PNA development projects. The reviewer questioned how this scope is unique within the portfolio of DOE projects looking at PNA systems.

Reviewer 3:
The reviewer stated that some ambiguities exist in the "Future Work," e.g., "studying effects of their gaseous species on PNA performance." The reviewer requested more specification of "other species." Slide 17 states, "e.g. hydrocarbons." The reviewer wondered if that could have been water content or HC only. These are just examples. The reviewer wondered why "e.g." and that far more clarity is warranted.

Reviewer 4:
The reviewer reported that there appears to be no plan to do full-size catalyst preparation and/or engine testing on some promising candidate catalysts.

Reviewer 5:
The reviewer is looking forward to the S work.

Reviewer 6:
The reviewer observed that HTA is not directly addressed until the summary slide. Dealumination is a different process from sintering. The reviewer would like to have some way to distinguish the two in the future work. The investigators seem to recognize this distinction; however, the reviewer could not see anything in the future work that is an attempt to make this distinction.

The reviewer would really like to see the dependence of the Al sites on aging duration, and also would like to see what the increase of palladium oxide is versus aging time. The reviewer questioned if there is any information on the sulfur build up in the zeolite. The reviewer was not sure that the density functional theory has value in this.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that this project aims at providing promising low-temperature emission control technologies, a critical enabler for high-efficiency engines, including CNG vehicles.

Reviewer 2:
The reviewer said that, yes, this Cummins-driven CRADA supports DOE objectives.

Reviewer 3:
The reviewer commented that both the PNA and CH_4 oxidation catalyst development work support DOE's objectives of improving the efficiency of internal combustion engines.

Reviewer 4:
The reviewer asserted that LTAT catalyst technologies must be exploited to support OEM needs to introduce highly efficient powertrains that are capable of meeting emissions standards. Most challenges occur in the cold start and colder portions of the drive cycles used to validate emissions compliance. These lean technologies address this need along with SCRs.

In response to questions on lack of resources to cover all the activities, the reviewer highlighted that PNNL is focused on only two projects, PNAs and CNG catalysts.

Reviewer 5:
The reviewer observed that the project has certainly targeted DOE's main objective. It could have produced more breakthroughs however given the project duration and the funding size. Though the challenge appears to have been too broad of an initial scope, the reviewer offered that the project could still benefit from further "refining" its objectives.

Reviewer 6:
The reviewer remarked that, at this point, there are enough holes in this work regarding the history of the samples that it is not going to engender outside research. The reviewer requested that the team disseminate sufficient information to start some other studies.

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 resources and funding appear to be sufficient.

Reviewer 2:
The reviewer commented that resources seem sufficient.

Reviewer 3:
The reviewer indicated that the project seems to have sufficient resources for conducting fundamental studies on catalytic materials and chemistry, as in the past, but full-size catalyst preparation and engine testing, if planned, would require significantly more resources.

Reviewer 4:
The reviewer observed that, with the CRADA cost share from Cummins, this project appears to be appropriately funded for its goals, especially with the adjusted focus to PNA and CH_4 oxidation only.

Reviewer 5:
The reviewer noted that, pursued at PNNL's unique laboratory capabilities, the project appears to have enjoyed sufficient resources. It is, however, planning, timeline, focus, know-how management, priorities, and execution which appear to have hindered stronger progress.

Reviewer 6:
The reviewer affirmed that, until there is a clear focus on the application, the reviewer views this project as excessively funded.

Presentation Number: acs119
Presentation Title: Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NO_x and Soot Emission Reduction
Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Presenter
Ken Rappe, Pacific Northwest 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 and well-planned.

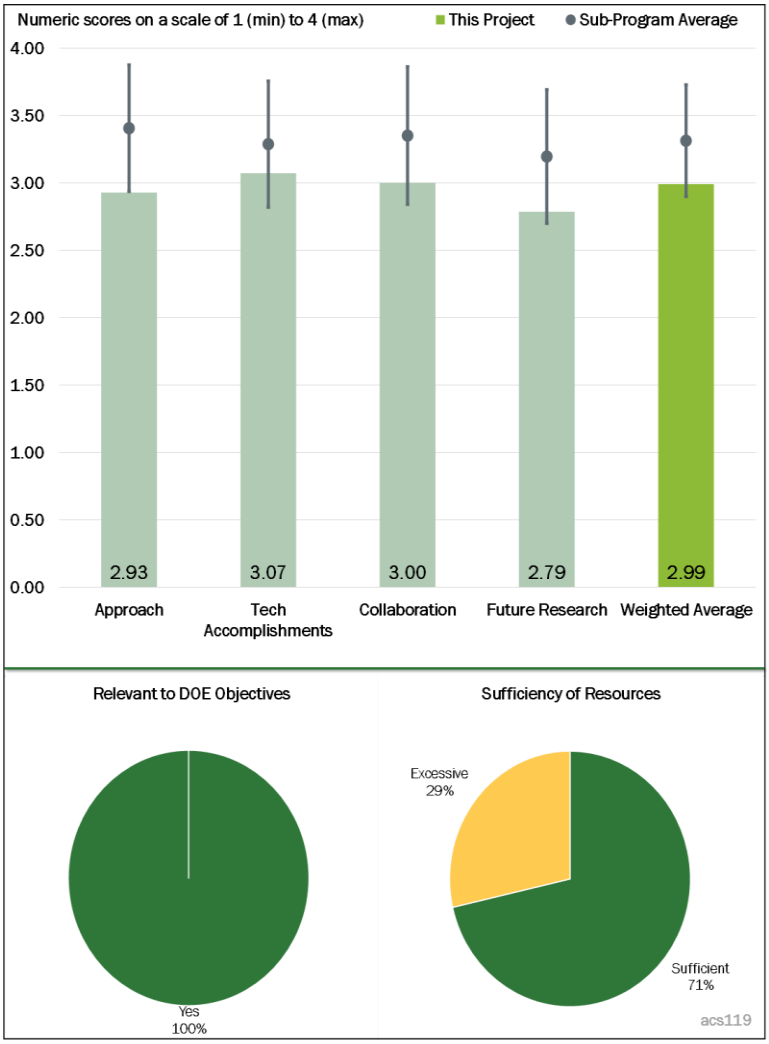

Figure 1-29 - Presentation Number: acs119 Presentation Title: Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NO_x and Soot Emission Reduction Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Reviewer 1:
The reviewer stated that the development of multifunctional catalysts is an important area of research to minimize the packaging requirements of OEMs, while improving system performance by more closely coupling the aftertreatment to the engine. The concept of washcoating a DPF with SCR material is a practical extension of the need addressed above. Although this is not a new idea, incorporating additional washcoat components to improve the NO_x and particulate number (PN) function of the catalyst is a desirable feature that also increases the SCR volume for NO_x control. The reviewer also commented that incorporating selective catalytic oxidation (SCO) components into the washcoat is a logical and appropriate addition to the development process.

Reviewer 2:
The reviewer observed that the shared approach seems fine, although it is not clear how much direct interaction there is between PNNL and PACCAR.

Reviewer 3:
The reviewer noted that this project shows the impact of bromine (Br)/ZrO_2 and SCO on a combined SCR plus DPF performance. The reviewer appreciated this good work. It, however, at least as apparent from the presentation, appears "fragmented." For instance, while it is stated that adding ZrO_2 assists with high temperature selectivity, nothing is shown as the end impact on the temperature-dependent soot. The NO_2

reaction is also in the same setting. The reviewer suggested that descriptions (if not charts) could have clarified this.

Reviewer 4:

The reviewer remarked that when SCR and DPF functionalities are integrated into one device (SCRF), SCF performance characteristics are affected by many factors, such as the presence of soot near the SCR catalyst, a limited amount of SCR washcoat in the pores in the substrate wall, and competition for NO_2 between the fast SCR and passive soot oxidation reactions. The relative importance of these factors needs to be assessed and quantified for optimizing the integrated unit.

The reviewer commented that it appears that the approach taken here focuses only on the last factor related to NO_2 availability for the fast SCR versus passive soot oxidation reactions. However, it is not clear whether this has proven to be the most important issue (or the most critical limiting factor) in determining the performance of the SCRF. Because the soot tends to accumulate near the mouth of the pores within the substrate wall of the SCRF, NO_2 would be in contact with the soot first, thus being consumed for soot oxidation before the SCR reaction as in the current aftertreatment system, where a DPF is located ahead of a SCR catalyst. This leads the reviewer to question the validity of the "competition for NO_2" argument illustrated at the bottom of Slide 4.

The reviewer suggested checking the validity of this premise by examining how the NO_x SCR, and soot oxidation performances are affected when NO_2 is added to the gas stream from a gas bottle. Also, if it turns out that more NO_2 is indeed needed to improve/optimize the SCRF performance (especially passive soot oxidation), it is not clear why more NO_2 should be generated over the SCR catalyst, as this project is trying to accomplish. The reviewer questioned the plausibility of modifying diesel oxidation catalyst formulations to generate more NO_2. In fact, NO_2 generated from the SCR catalyst may/may not provide enhanced passive soot oxidation in an effective manner because it would require back diffusion of NO_2.

Reviewer 5:

The reviewer acknowledged that introducing a new type of material, such as metal-oxide component, into this program would be something new and interesting, which clearly has some advantage in improving high temperature selectivity, thus improving performance and durability. However, the reviewer inquired about low-temperature performance for the cold start, and whether this system can meet emissions standards. In addition, the approach seems only to address the interaction between the fast SCR reaction and soot consumption with NO_2 (Slide 4). The reviewer suggested including the standard SCR reaction, because it would consume NO_2 as well, even though the timescale may be different between the fast and standard SCR reactions.

Reviewer 6:

The reviewer commented that this project seems to go down every rabbit hole that pops up. There is a lack of a goal-driven approach.

Reviewer 7:

The reviewer observed that this project has been ongoing in some form or another since 2010/2011, and yet there seems to be little progress. The reviewer questioned the approach and the continuation of this project and pointed out that the project team even agreed with previous reviewer comments that the approach is naive, difficult, and unlikely to be successful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer offered that good progress has been made on SCR catalyst modification to increase NO_2 production via selective oxidation of NO.

Reviewer 2:
The reviewer stated that the zirconia attachment to the zeolite framework is especially interesting.

Reviewer 3:
The reviewer said that significant characterization of the SCRF catalyst has occurred in this project. The inclusion of barium (Ba) for additional NO_x storage, SCO for NO oxidation, and ZrO_2 as a way to stabilize the catalyst and improve the NO_x and NH_3 reactions are all logical extensions of the base work and should be pursued. However, the reviewer offered that more consideration should be given to the effect of the washcoat on backpressure and overall system response. Additionally, packaging considerations will have to be given consideration in conjunction with the amount of volume that will be needed when using lower loaded SCR components that are present in filters.

Reviewer 4:
The reviewer stated that it appears that the project team is making progress against the agreed milestones, although the one go/no-go gateway has been delayed from February 2018 to summer 2018. Focus is on SCR on DPF for HD applications, especially where there need to be differences from similar LD applications. The reviewer indicated that an interesting result was that so-called impregnation of CuO into the ZrO_2 matrix formed a new species phase. Also, it was interesting to the reviewer to see how adding Ba to the zirconia improves the NO_x conversion, especially the identification of the aging mechanism that affects low-temperature activity.

The reviewer reported that it was good that the team has been looking at catalyst durability, especially with respect to aging. The reviewer requested the project please provide details on how PACCAR is coating the SCR-DPF systems, because it is relevant to what DOE is funding.

Reviewer 5:
The reviewer commented that progress has been made. Though the idea of using Ba/ZrO_2 is interesting, what is shown is necessary information, but is not sufficient to make a convincing case. For instance, it is well-known that Br is sensitive to S deposit; nothing is said about this. Slide 11 on step mechanisms of reactions (NO to NO_2 conversation in fast SCR) is from Tronconi, but the source is not cited/given credit.

Reviewer 6:
The reviewer highlighted that progress has been overall slow, and there continues to be delays (February 2018 go/no-go decision). It is hard to imagine that significant progress or accomplishments will be achieved on this project. The reviewer observed evidence of "CLEERS work" mixed in, noting several similarities with ACS023. In addition, there is some very fundamental work going on that it is not clear how it is relevant or translates to the CRADA work.

Reviewer 7:
The reviewer said that it seems that progress has been made on the high-temperature side. However, the reviewer noted that the low-temperature side seems to face some issue (Slide 12), which would be one of the major issues to meeting standards, specifically the cold FTP cycle. It was not clear to the reviewer how the authors would handle this major low-temperature issues moving forward. It would be more helpful if the authors can address this issue even with a plan.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the role between PNNL and PACCAR has been clearly defined, and the collaboration and coordination between these two partners seems to be good.

Reviewer 2:
The reviewer remarked that the interaction with PACCAR seems to be strong. The reviewer would prefer to see additional technical voices at the table.

Reviewer 3:
The reviewer acknowledged that the combination of PNNL characterization and formulation capabilities and PACCAR vehicle powertrain development works well for this project. However, the reviewer suggested that this project would also benefit from a catalyst washcoater to provide additional insight in how to optimize including washcoat components for proper function.

Reviewer 4:
The reviewer observed that the project is a CRADA between the key partners, PNNL and PACCAR. Nevertheless, it feels like the two partners are operating in parallel and only periodically exchanging information instead of operating as a combined team.

Reviewer 5:
The reviewer reported that PNNL had good collaboration with PACCAR, but questioned whether suppliers were involved. In one slide, it says that PACCAR is doing the coating of the substrates, but that seems unlikely. The reviewer requested knowing who else the team is working with on this.

Reviewer 6:
The reviewer indicated that it is not clear from the presentation slides what the specific nature and extent of collaboration are between PNNL and PACCAR.

Reviewer 7:
The reviewer said that PNNL and PACCAR are the only members of the team. It was not clear to the reviewer why such a challenging problem and external know-how has not been integrated into the team. The reviewer suggested that the presence of a catalyst supplier strong in SCR-DPF R&D and familiar with commercial benchmarks would have been very helpful. In the opinion of this reviewer, Umicore could be a good partner for this due to its R&D capability in this area (though the intention is not to promote one supplier versus another). The presentation also stated that PACCAR does the coating (Slide 14). The reviewer considered this strange to hear because PACCAR is not a coater. The reviewer questioned if it meant that "coated parts are supplied through PACCAR." The reviewer highlighted that further clarification is needed. This is a complex problem; there is very little room for ambiguity or for playing with concepts. Clarity in strategy is of utmost importance.

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 project has a reasonable future work plan based on the accomplishments so far.

Reviewer 2:
The reviewer offered that the proposed research is a logical extension of the work to date, but it does not seem compelling. Be prepared to answer why it should get funded and not others that may have more immediate relevance. The reviewer also asked how the results of this work will be publicized.

Reviewer 3:
The reviewer observed that it is stated (Slide 17) that future work is to focus on increasing NO oxidation (to NO_2). While increased NO_2 formation could assist soot removal, increased NO_2 by itself is a necessary condition for soot removal, but not sufficient, as also temperature and NH_3 play key roles, amongst other

factors. The reviewer suggested to the investigators list "future work" via considering, first, what they want the end targets to be. Once those targets are clear, the next step is to set interim milestones (fitting the project timeline) to reach end targets. Looking at this presentation, it appears that time may not be a driver, which could take this exploration into a convoluted pathway with no clear time-based execution.

Reviewer 4:
The reviewer noted that the team should have a better plan to improve the functionality of the washcoat components. More understanding of the reaction mechanisms is required to appropriately alter the components. Using manganese (Mn) and other species that have been studied before at PNNL have limitations that are not appropriate for exhaust conditions. Also, the reviewer concluded that faster feedback from PACCAR would benefit direction at PNNL.

Reviewer 5:
The reviewer highlighted the need to address interaction between the standard SCR reaction and soot consumption with NO_2 in the future work. In addition, low-temperature behavior is equally important as durability, which should be addressed as well.

Reviewer 6:
The reviewer noted that it seems like progress is very slow and struggles to be relevant to real-world needs for PACCAR.

Reviewer 7:
The reviewer asserted that the future work is still following up all the sidetracks, and that there is no focused pathway to a product.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that this project directly addresses issues of durability for heavy HD diesel engines. It indirectly addresses issues of cost-effective emissions control, especially for heavy HD diesel engines.

Reviewer 2:
The reviewer noted that all the information generated in this project probably has use in some part of aftertreatment.

Reviewer 3:
The reviewer commented that this work appears to be relevant to the development of aftertreatment systems that fit the packaging and temperature requirements of OEMs. This effort is supported in the OEM community.

Reviewer 4:
The reviewer said that, yes, it generally supports DOE objectives.

Reviewer 5:
The reviewer suggested that SCR-on-DPF may be one of the trends moving forward, which can reduce overall packaging volume and potentially improve performance and durability, thus overall system cost.

Reviewer 6:
The reviewer observed that any increase in soot oxidation in emission control systems (in this case in a combined SCR-DPF) would help reduce system backpressure, in turn increasing fuel economy, meeting DOE's strategic goal. Apart from this long-term goal, and showing some benefits of metal oxides (ZrO_2) in a DPF-SCR in the interim, in the opinion of this reviewer this project will have a hard time meeting, by 2020, its ultimate goal of yielding an optimized SCR-DPF beyond existing industry benchmarks.

Reviewer 7:
The reviewer indicated that integration of NO_x conversion over SCR catalyst and passive soot oxidation over DPF into one device for HD applications would be beneficial from cost, packaging, and thermal management perspectives.

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 resources appear to be sufficient. No change in resources is recommended.

Reviewer 2:
The reviewer stated that it looks like the budget received from DOE to date is less than what would have been expected based on the total budget. Nevertheless, to date it looks to the reviewer like the project team has been able to meet their project milestones with the available budget.

Reviewer 3:
The reviewer noted that the current resources seem sufficient in light of the project scope and schedule/milestones.

Reviewer 4:
The reviewer commented that, while good work takes time, there is immediate need for enhanced soot-oxidation in a SCR-DPF. This team should seriously consider integrating external expertise of a coater for several reasons. First, to refine its approach (does not mean sacrificing its novelty). Another reason is to make sure the intermediate steps are not only tangible but fit in a reasonable timeframe for the stakeholders. Lastly, it could integrate industry's notable expertise in this investigation, accelerating its undertaking.

Reviewer 5:
The reviewer observed that the team should have enough funding to complete the research, because only 41.7% is consumed.

Reviewer 6:
The reviewer indicated that based on the progress, the resources seem excessive.

Reviewer 7:
The reviewer offered that too many side trip investigations cost money.

Presentation Number: acs120
Presentation Title: Enabling Lean and Stoichiometric Gasoline Direct-Injection Engines through Mitigation of Nanoparticle Emissions
Principal Investigator: Will Northrup (University of Minnesota)

Presenter
Will Northrup, University of Minnesota

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 and well-planned.

Reviewer 1:
The reviewer stated that this activity addresses an important area within the emissions control milieu—the generation and control of PM during lean combustion. In the reviewer's opinion, the general mechanisms of PM formation and control require significant fundamental investigation, and the reviewer found the team's use of the in-cylinder luminosity technique to be intriguing and exciting. The reviewer commented that the ability to use this tool to diagnose diffusion flames as a direct source of enhanced PM formation was excellent.

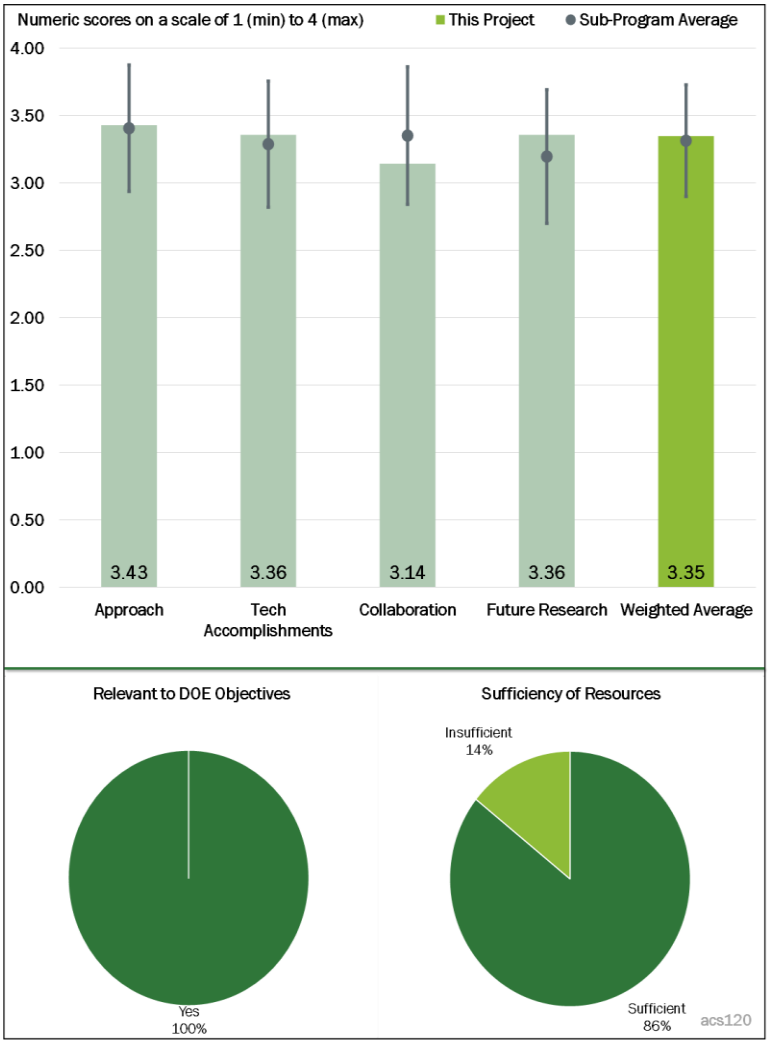

Figure 1-30 - Presentation Number: acs120 Presentation Title: Enabling Lean and Stoichiometric Gasoline Direct-Injection Engines through Mitigation of Nanoparticle Emissions Principal Investigator: Will Northrup (University of Minnesota)

Reviewer 2:
The reviewer observed solid plans to complete the investigation of the effects of different fuels on the PM/particle number (PN) emissions from the vehicle and then to investigate the effect of aftertreatment with those same fuels.

Reviewer 3:
The reviewer commented that PM emissions from gasoline engines are indeed not understood and adequate methods are yet to be developed. This project targets overcoming these barriers.

Reviewer 4:
In the reviewer's view, the approach seems a reasonable mix of focus on the fundamentals of fuel, in-cylinder particle analysis, as well as fuel chemistry. Also, there is a mix of models borrowed from the literature integrated into the analysis of test data.

Reviewer 5:
The reviewer noted that PM emission control is of considerable importance for aftertreatment system development of the next-generation gasoline vehicles. Fuels may have a profound impact on the actual PM emission control efficiency, and a systematic fundamental study is largely absent in the area. The reviewer stated that the project picks the right perspective to tackle the problem in the face of future needs for accurate measurement mass and number in real-time engine dynamometer operations.

Reviewer 6:
The reviewer remarked that the approach over several years appears well thought out and sequenced while finding it unusual to see a project at the AMR for the first time in its third year. Maybe, the reviewer opined, there were timing issues in the project that were not covered in the slides, but the second year is an important time to be receiving suggestions because there is time to respond.

Reviewer 7:
The reviewer suggested an increased emphasis on transient testing, including some several operating regions from certification test cycles. The reviewer was of the opinion that it might be useful to add an intermediate ethanol—say 30%—to understand at what level the increase in particulates is first seen. The reviewer asserted that injection technology needs updating by going up to 300 bar.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer pointed out that the team has made excellent progress on technical elements for a difficult project. The test stand is generating very useful and complex data.

Reviewer 2:
The reviewer had several positive comments: Using in-cylinder luminosity gave unique insight. The direct collaboration with fuel manufacturers to correlate fuel characteristics to combustion and PM was encouraging. The team was also able to demonstrate the link between combustion mode and generation of PM and, more specifically, highlight the case where the correlation breaks down (lean homogeneous). The reviewer appreciated the team's attempts to provide a means of linking particle density and diameter for real-time PN to mass.

Reviewer 3:
The reviewer stated that it was nice to see a systematic evaluation of stoichiometric, homogeneous lean, and stratified lean operation on the PM/PN emissions and then the correlation between the PM and the PN for the three operating modes. It was interesting to the reviewer that the high ethanol fuel produced the highest PM/PN under lean homogeneous mode, but the lowest PM/PN under lean stratified mode and the next-to-lowest PM/PN under stoichiometric operation.

Reviewer 4:
The reviewer noted that the following are all important: the fundamental understanding of the impact of ethanol—the particulate matter index (PMI) does not apply to lean burn—and the finding of high sub-23 nanometer (nm) particles for lean GDI. The reviewer commented that it is important that a physical/chemical justification be provided that explains the above.

Reviewer 5:
The project appears to be on track overall to the reviewer; however, it does appear that milestone 3.3 is a little behind schedule. The principal investigator (PI) does appear to have a holistic explanation for the PM/PN formation across fuel chemistry and combustion.

Reviewer 6:
The reviewer found the results thus far to be very interesting. The source of the unexpected sub-23 nm particles needs to be confirmed. It appears that a choice on a GPF and TWC was made, but not discussed. Those studies in Task 4 are incomplete, but the reviewer suggested that a view of how the team is going, especially in the third year, beyond the figure in the top of Slide 10 would have been very useful. The reviewer assumed that this has all been done well. It appeared to the reviewer that the analysis tools are very relevant and are giving good data.

Reviewer 7:
The reviewer observed that the proposed project involves abundant test cell work that requires substantial hardware and labor input, and unexpected delays are not uncommon is such context. However, the reviewer noted that the key findings so far are more qualitative than quantitative, mainly due to the test cell engine control issues as the PI claimed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that evidence was presented of good collaboration with FCA, BP, ORNL, and AVL.

Reviewer 2:
The reviewer found the team to have a good range of collaborators drawn from both industry and academia. The reviewer noted that the teams' wishes to expand the range of partnerships as the project progresses, but is the reviewer appreciated that this is still the early days in the activity.

Reviewer 3:
The reviewer stated that collaboration among the university, industry partners, and ORNL appears to be well coordinated. Given the significance of particle treatment inside a coated GPF, the reviewer said that adding catalyst expertise to the team appears warranted.

Reviewer 4:
The reviewer asserted that collaborators appear potentially sufficient to a broadly based project such as this. The reviewer suggested that it would be good to have more detail on what parts of FCA, BP, and ORNL are involved along with the names of those resources thus far into the project, as this helps provide understanding of the directions being covered. The reviewer asked if there are meetings by phone or in person by collaborating organizations and what their frequency is.

Reviewer 5:
The reviewer commented that the involvement of FCA and BP could be deeper on the engine and fuels aspects. The reviewer noted that AVL provides expertise for the test stand diagnostic. The reviewer asserted that the contribution of ORNL was not clearly articulated.

Reviewer 6:
The reviewer stated that there is much work done in other groups on understanding particulates from lean GDI and impact of GPFs. The reviewer suggested that it will be good to collaborate with those projects and also differentiate the work being done here.

Reviewer 7:
The reviewer acknowledged that the project seems to have the right partners and collaborators to work together. However, as previously mentioned, the reviewer stated that the project is a laborious work that must require high expertise in hardware and controls. The resources seem to be limited in the opinion of 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 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 logical plan going forward.

Reviewer 2:
The reviewer commented that the project is still in its early stages but found it encouraging to see that the team has a vision for future activities that are closely aligned with the needs of their partners and the scope of the DOE mission. The reviewer noted that the team is also showing a willingness to expand the activities, again hopefully with a perspective of aligning with a wider range of industry partners to maximize the value and impact of these activities.

Reviewer 3:
The reviewer indicated that the project appears to be well organized and planned. The PI has a clear list of targets and deliverables in the future work list. The reviewer stated that the task "Fuel-dependent soot oxidative reactivity" markedly calls for the need to have a particle-experienced catalyst chemist on board the project.

Reviewer 4:
The reviewer suggested that the investigation into the effects of aftertreatment with the different fuels will be interesting. The reviewer asked if there are plans to investigate different GPFs with different characteristics or whether the planned work is confined to a single GPF.

Reviewer 5:
The reviewer found the future work to be well-planned out. The reviewer recommended that the team investigate multiple GPF+TWC configurations in order to generate more reliable and comprehensive conclusions.

Reviewer 6:
The reviewer stated that the items in Tasks 3-6 that are going to be covered will be very important to understand the part that particulates are playing in aftertreatment issues for GDI engines. The reviewer pointed out that stoichiometric engines are covered in the title of the project and results are needed there, if only as a reference. The reviewer assumed that those are included, if not explicitly.

Reviewer 7:
The reviewer proposed that it will be very useful to add a definite objective that aims to explain fundamentally why there is an increase in sub-23 nm particles, why the PMI does not apply to lean GDI (and whether there is another relationship that holds), and why PN increases at high ethanol. Also, the reviewer would like to see an increase in the transient experiments.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that this is a highly relevant project in support of DOE objectives.

Reviewer 2:
The reviewer responded affirmatively and commented that the goals of this project are well-aligned with the United States Driving Research and innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) ACEC Roadmap.

Reviewer 3:
The reviewer noted that lean GDI offers improvement in fuel economy, but particulates need to be understood. Also, the reviewer said that the study of higher ethanol content fuels is in line with the direction for increased use of renewable fuels.

Reviewer 4:
The reviewer asserted that PM/PN aftertreatment will be necessary for GDI vehicles to satisfy the most stringent PM/PN standards.

Reviewer 5:
The reviewer found the approach to the R&D to be technically sound and noted that the team is employing state-of-the-art techniques to probe deeply into the mechanisms of PM generation. As such, the reviewer commented that the team is already realizing significant technical progress towards fulfilling project goals as well as providing a high level of value to their industrial partners. The scope of the partnership is good but should be expanded given the relevance, value of the data, and insight generated. The reviewer emphatically judged the potential value of this project to be at the highest level and expected to see further interesting developments in 2019.

Reviewer 6:
The reviewer observed that the understanding of what is needed to deal with particulates and meeting emission standards are key to developing strategies for using GDI engines to meet fuel economy and emission standard guidelines.

Reviewer 7:
The reviewer remarked that particulate matter emission control is of considerable importance for the aftertreatment system development of the next-generation gasoline vehicles. New knowledge is anticipated in the area of fuel impacts, GPF+TWC configuration impacts, and measurement strategies. The reviewer stated that the project fits the scope.

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 are excellent facilities.

Reviewer 2:
The reviewer observed that the resources for this project appear to be sufficient.

Reviewer 3:
The reviewer stated that resources seem sufficient given the progress made year to date and the future work planned.

Reviewer 4:
The reviewer noted that the resources appear to be sufficient for this project.

Reviewer 5:
The reviewer said that there seems to be a good balance between resource and delivery. Obviously, if the scope of activities is expanded, the funding should reflect this.

Reviewer 6:
The reviewer asserted that the experimental resources appear to be well provided at the University of Minnesota. The reviewer commented that further resources may be coming from collaborators, but are not spelled out in this presentation.

Reviewer 7:

The reviewer noted that the project seems to have the right partners and collaborators to work together. However, as mentioned previously, the project is a laborious work that must require high expertise in hardware and controls. The reviewer commented that the resources seem to be limited according to the non-conclusive progress and preliminary interpretation of the data.

Presentation Number: acs121
Presentation Title: A High Specific Output Gasoline Low-Temperature Combustion Engine
Principal Investigator: Hanho Yun (General Motors)

Presenter
Hanho Yun, General Motors

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 and well-planned.

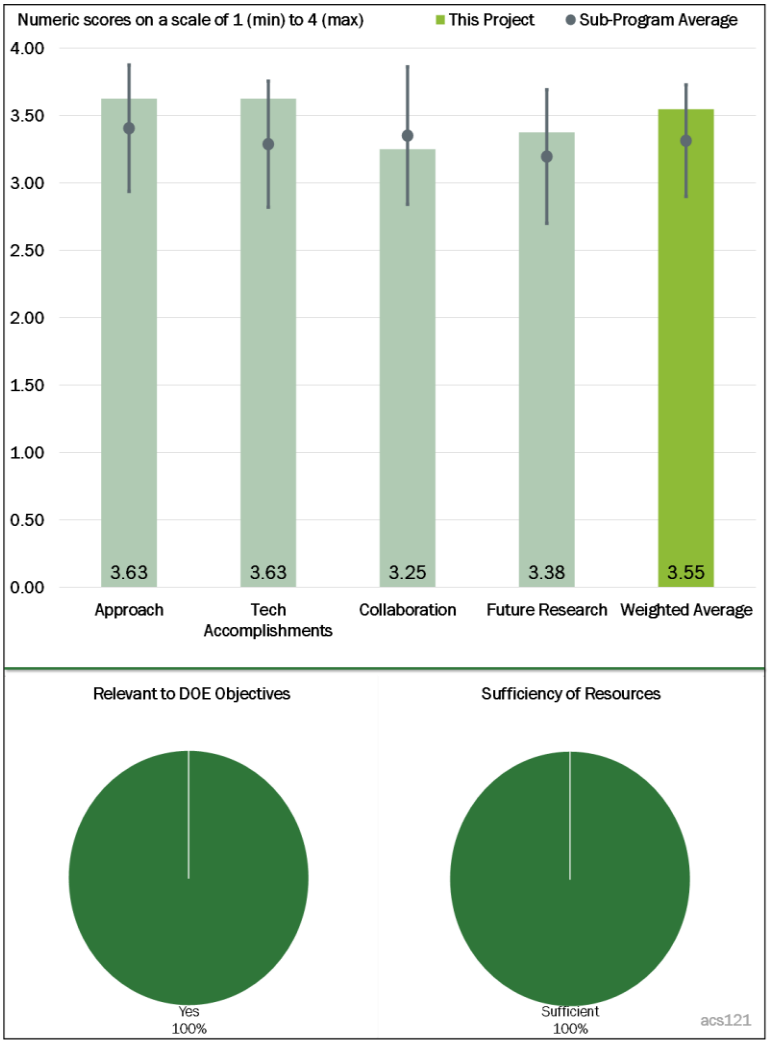

Figure 1-31 - Presentation Number: acs121 Presentation Title: A High Specific Output Gasoline Low-Temperature Combustion Engine Principal Investigator: Hanho Yun (General Motors)

Reviewer 1:
The reviewer pronounced the project to be a very strong and well thought out approach to addressing the technical barriers of significant improvements in fuel economy through the introduction of LTC in combination with boosted SI operation. The reviewer noted that the approach integrates all key areas—downsizing and boosting, low-cost emissions controls, lean LTC, LTC ignition control, and physics-based control. The reviewer stated that the approach appears very ambitious for the funding level, but great progress has been made. While all of the key areas show great innovation in the approach, the reviewer found the low-temperature ignition system to be especially interesting. The team has developed a very unique and controllable ignition system without excessive complexity. The reviewer said that this appears to be an important enabler for ensuring robust operation across the multiple combustion strategies being used to cover the entire speed-load operating range.

Reviewer 2:
The reviewer observed that this project is a good combination of advanced injector, ignition system, air handling, aftertreatment, and combustion strategies to achieve the overall goal of improving fuel economy, engine robustness, and lower noise.

Reviewer 3:
The reviewer stated that the approach for LTC on this project looks well designed and thought out with the higher energy ignitions system able to address the unstable points of operation, thus contributing to a smoother transition between modes of operation.

Reviewer 4:
The reviewer thought that the approach was well done as the presenter explained the four strategies as a function of load. The key will be in the mode switching as load changes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that identifying the four modes of operation is a key accomplishment. The next step is mode switching in the view of the reviewer.

Reviewer 2:
The reviewer referenced prior comments. The reviewer stated that the technical accomplishments appear on target with excellent results. This includes a demonstration of 16% improvement in net fuel consumption with very low indicated NO_x for a 2,000 revolutions per minute (rpm), 2 bar net mean effective pressure condition. The reviewer pointed out that comparing HRRs for LTC versus conventional operation was very helpful in understanding the accomplishments and future opportunity. The reviewer commented that there was also a great example of how the ignition system "stabilizes" the combustion process to avoid "problematic" cycles, a great accomplishment. The reviewer noted that the final discussion on lean LTC and the use of ignition, multiple injection, EGR, and valving to extend load range was very helpful.

Reviewer 3:
The reviewer noted that good progress was made in demonstrating the feasibility of the technology and its advantages. It will be good to compare the brake specific fuel consumption of this technology with other, similar high-efficiency ICEs.

Reviewer 4:
The reviewer found the technical accomplishments to be detailed nicely and thoroughly. The reviewer said that this was very nice work completed with a lot of information on the slides that was not covered in the presentation. This reviewer would have liked more discussion on the valving strategy on Slide 11, but this was not extensively covered in the presentation so it was not clear what this chart is showing and how this was done.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the GM team has an impressive group of suppliers to bring together diverse expertise from across the industry. The reviewer was not sure the suppliers would technically be collaborators, but they are supporting the project to meet the objectives of the original proposal. The reviewer called this a great team.

Reviewer 2:
The reviewer stated that there was good collaboration with Tier 1 suppliers.

Reviewer 3:
According to the reviewer, there seemed to be a clear collaboration between GM and Delphi. The reviewer assumed that there was communication with the other four partners. The reviewer suggested that it would be good to highlight that in the next review.

Reviewer 4:
The reviewer noted that the partners/suppliers are well qualified and have significant expertise to offer to the project. However, by only using suppliers as partners, the team is excluding universities and national laboratories, which could strengthen the team and the project. The reviewer proposed that the team should consider adding these organizations to enhance the diagnostics or modeling aspects.

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 proposed future work was appropriately cited as mode switching.

Reviewer 2:
The reviewer commented that the proposed future research appears on target on what needed to be done to move this concept forward. The team is very aware of the barriers and challenges to developing a technology for market.

Reviewer 3:
The reviewer remarked that the project was mostly well planned, but there were no details on mitigating the risk if the aftertreatment system is not sufficient to meet the future NO_x target. Also, the reviewer asked about PN emissions.

Reviewer 4:
The reviewer said that the future work identifies items like developing a "seamless" mode-switching strategy and "robust" hot and cold operation. The reviewer asked what the definition of these terms was. The reviewer stated that it would be better to identify specific, measurable goals.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that LTC is a key strategy for meeting future emissions and fuel economy. The reviewer recommended that DOE continue this research.

Reviewer 2:
The reviewer pointed out that this project clearly supports the overall DOE objectives by developing a technology and strategy for significant improvements in fuel economy while addressing critical barriers and challenges for market introduction.

Reviewer 3:
The reviewer said that this project addresses multiple objectives relevant to DOE: namely, improvement to fuel economy, advancing LTC regimes for gasoline engines, engine controls for LTC, and emissions control challenges for advanced engine concepts.

Reviewer 4:
The reviewer agreed that this project demonstrates advanced ICE technologies, which support the DOE objectives of reducing fuel 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 found the resources to be sufficient to achieve the stated milestone.

Reviewer 2:
The reviewer said that the resources for this project look appropriate.

Reviewer 3:
The reviewer indicated that resources seem appropriate.

Reviewer 4:

The reviewer stated that the team appears to be delivering a significant amount for the allocated resources. However, there were not comments on the resources being insufficient and the team appears on track to meet all deliverables.

Presentation Number: acs122
Presentation Title: Solenoid Actuated Cylinder Deactivation Valvetrain for Dynamic Skip Fire
Principal Investigator: Hermes Fernandez (Delphi Automotive Systems, LLC)

Presenter
Hermes Fernandez, Delphi Automotive Systems, LLC

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 and well-planned.

Reviewer 1:
The reviewer stated that the approach is very good. The reviewer said that the focus on the minimizing OEM engine integration modifications is great. This will be very important to OEM willingness to integrate across multiple platforms. The reviewer remarked that the approach is very well thought-out from engine control module to active control mount to solenoid actuation. The selection of electrified actuation over hydraulic also makes sense to the reviewer, especially with increased electrification infrastructure on current and next-generation vehicles.

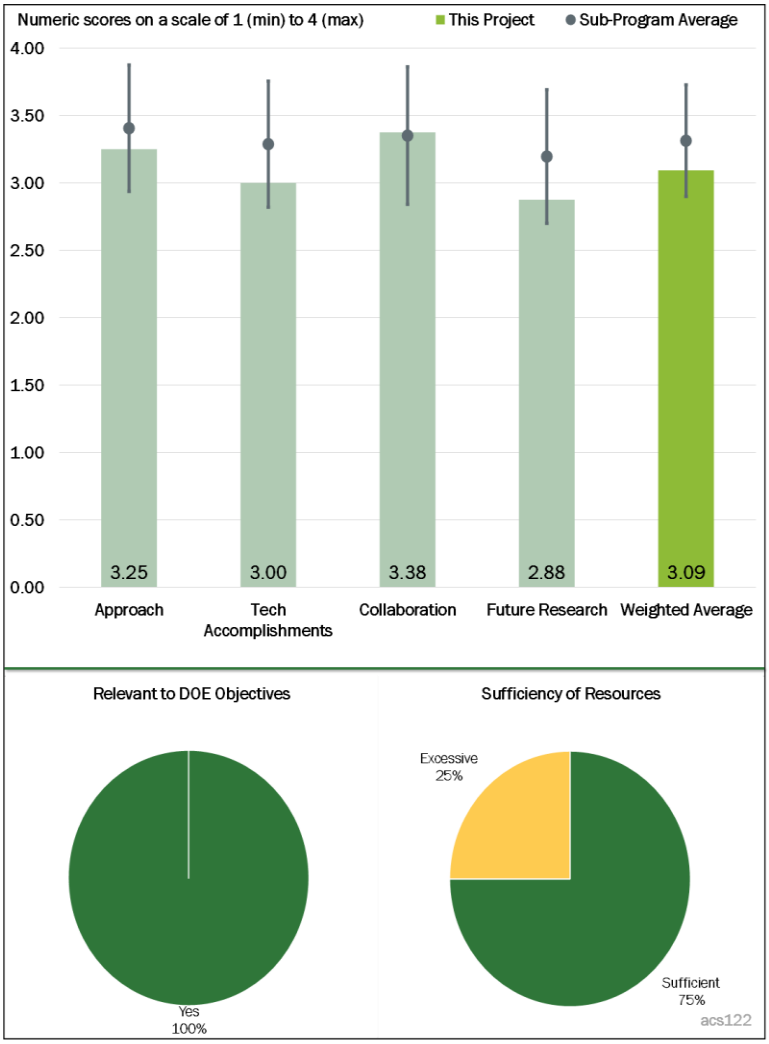

Figure 1-32 - Presentation Number: acs122 Presentation Title: Solenoid Actuated Cylinder Deactivation Valvetrain for Dynamic Skip Fire Principal Investigator: Hermes Fernandez (Delphi Automotive Systems, LLC)

Reviewer 2:
The reviewer commented that the approach of using a novel CD strategy to achieve 8%-10% fuel economy improvements is well-designed. The reviewer reported that the team is using engine simulation along with design to accelerate the concept and that a high-level overview of the process was given. The reviewer suggested that more details of the integrated system approach could have been provided. The reviewer stated that the figure on Slide 5 helped convey the concept, but comparing this approach to downsizing or conventional CD was not provided. The reviewer said that there were not many details on the underlying pathways of improvement (other than reduce pumping losses and "improve combustion thermodynamics").

Reviewer 3:
The reviewer opined that the team is applying the Skip Fire technology to SAE type 2 valve train architecture to facilitate the market penetration of the technology. The team is using electric actuators to simplify integration on-engine, especially compared to hydraulic actuators. It was not clear to the reviewer that the

project really addresses purely pre-competitive issues though, given that the system is about ready for production release.

Reviewer 4:
The reviewer noted that the approach is sound for the rocker arm. The baseline fuel economy is for a modern engine that does not have CD. The reviewer recommended that the team compare DSF versus the authors' intended baseline without CD and then compare those results to modern engines with fixed CD (i.e., not DSF).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that the technical accomplishments are strong and consistent with the plan. The reviewer noted that the team developed and reviewed 22 concepts before reducing to 6 for further study. The reviewer had a question about the durability of the lock pin, which was addressed somewhat during the question and answer (Q&A) session with another reviewer. The team is evaluating durability with standard methods. The reviewer noted that progress on milestones is also very good.

Reviewer 2:
The reviewer stated that work seems to be progressing well on the rocker arm development, and testing will occur later.

Reviewer 3:
The reviewer found the accomplishments to date to be appropriate, but seemed thin compared to what is in store for FY 2018. The final design concept is complete, including on-engine packaging analysis for the initial demonstration application. The reviewer pointed out that the team has tried to take a manufacturer-neutral approach to designing the system. The reviewer noted, as an aside, that the target fuel economy improvement is over the drive cycle and compared to a modern engine without CD.

Reviewer 4:
The reviewer stated that this is the first year of the project. According to the reviewer, the accomplishments focus on the high-level aspects of the engine simulation, the use of solenoid actuation, and design analysis. The importance of the actuator driver module development was presented. The reviewer remarked that more technical details of what the underlying improvements pathways could be presented. The reviewer stated that the presenter did not have information regarding what happens to exhaust temperature during different firing densities and was very much focused on design elements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the Delphi team is partnered with Tula Technology and appears to have a great partnership and strong coordination. Combining a strong supplier like Delphi and the developers of the DSF technology make for a strong team.

Reviewer 2:
The reviewer noted that the team is Delphi Technologies and Tula Technology. It looks like the team has made a reasonable split of the work between the two based on their strengths and interests.

Reviewer 3:
The reviewer found the partnership between Delphi and Tula to be well coordinated and a great match for achieving the technical goals of the project. It was not clear to the reviewer if the project will be considering aftertreatment challenges as presented.

Reviewer 4:
There is clear collaboration between Delphi and TULA, according to the reviewer, who recommended comparing DSF to fixed CD for a better understanding of the benefits of DSF.

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 the proposed future research makes sense in meeting the objectives of the program. The overall project approach, which also directs the future research, is excellent.

Reviewer 2:
The reviewer remarked that the proposed future research looks to follow a well-developed product development cycle plan. The remaining challenges and barriers to actually achieving the targets are not well laid-out in terms of linking to the proposed future research.

Reviewer 3:
The reviewer rated the project as good and stated that the rating would have been higher if there was comparison to fixed CD to better understand DSF benefits.

Reviewer 4:
The reviewer opined that the plan for FY 2018 seems ambitious, even though one of the milestones is nearly met. The reviewer pointed out that the team plans to build and test the demonstrator engine, with particular emphasis on its fuel economy. Nevertheless, if General Motors is introducing DSF on a couple of production engines starting in 2019, the reviewer questioned why the Department of Energy needs to subsidize the development of the technology. For example, the reviewer noted, several of the proposed FY 2019 activities look to support production, such as durability or design validation testing, which are not development activities. Demonstrating the fuel economy benefits is absolutely critical for this project.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that the dynamic skip fire approach is very relevant to meeting the overall DOE objectives by enabling engine operation at conditions of maximum BTE for a wider range of speed/load points. For a further strengthening of the relevance, the reviewer mentioned that Delphi is addressing potential barriers and challenges to widespread market implementation. More specifically, according to the reviewer, Delphi is developing a system that an OEM will be able to integrate with minimal modifications, and they are ensuring durability of the device.

Reviewer 2:
The reviewer stated yes; various forms of CD are being used to improve aftertreatment systems and fuel economy. This reviewer further advised that it will be good to understand the benefits of DSF.

Reviewer 3:
The reviewer noted that the purpose of the dynamic skip-fire technology is to improve engine efficiency, especially in boosted direct-injection spark-ignition engines.

Reviewer 4:
The reviewer stated that this project supports overall DOE goals of improving fuel economy, and addressing barriers to use advanced technologies. The reviewer opined that the objectives were only loosely tied to the U.S. DRIVE goals.

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 use of electrically actuated dynamic CD is a difficult endeavor. The team appears to have the resources to accomplish the proposed goals.

Reviewer 2:
The reviewer commented that resources seem sufficient.

Reviewer 3:
The reviewer stated that resources appear to be sufficient. The reviewer observed that there were no comments/concerns from Delphi nor any issues in the presentation.

Reviewer 4:
The reviewer found the overall budget to be appropriate for the scope of work. Nevertheless, if DSF is being introduced into production vehicles, the reviewer questioned why the Department of Energy needs to subsidize 50% of this technology demonstration project.

Presentation Number: acs123
Presentation Title: Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines
Principal Investigator: Tobias Schaedler (HRL Laboratories)

Presenter
Peter Andruskiewicz, General Motors

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 and well-planned.

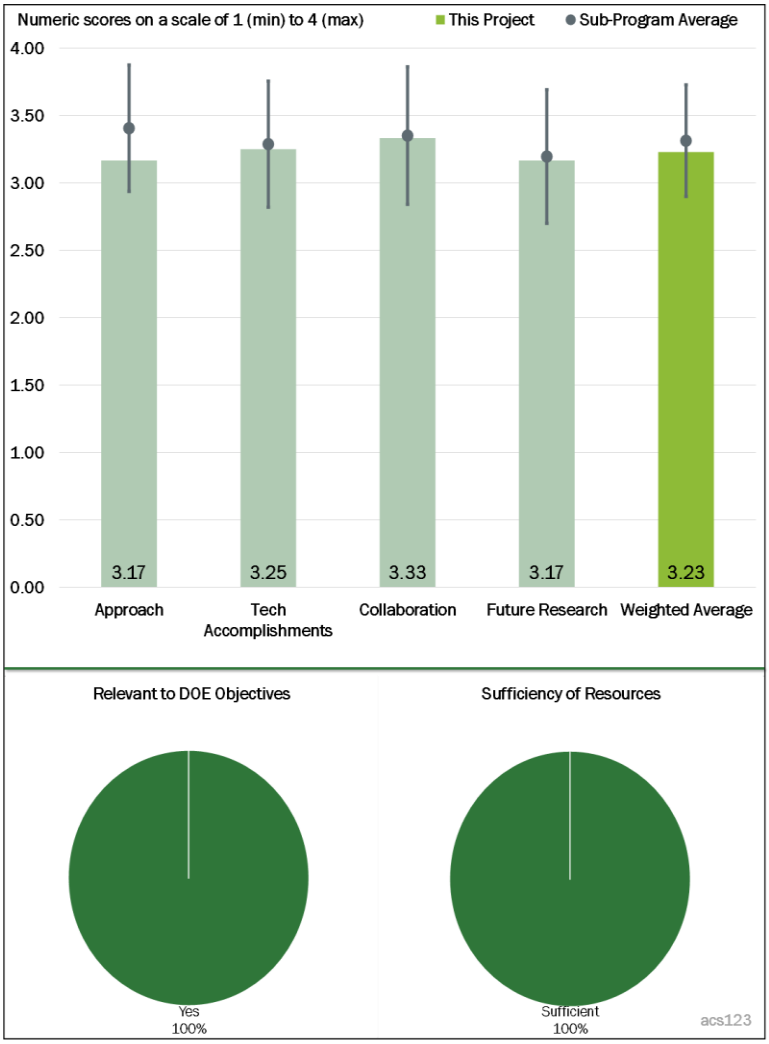

Figure 1-33 - Presentation Number: acs123 Presentation Title: Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines Principal Investigator: Tobias Schaedler (HRL Laboratories)

Reviewer 1:
The reviewer opined that a "Temperature Following Thermal Barrier Coating" would certainly be superior to simple ceramic thermal barriers. The reviewer stated that the modeling appears to be solid and shows real potential for benefits. The approach to address the significant challenges of applying sintered nickel micro-shell spheres is very reasonable. The reviewer noted that this is a high-risk, challenging enabling technology with potential for significant payoff if successful. The reviewer said that this is an appropriate use of DOE resources for low TRL research.

Reviewer 2:
The reviewer liked this project very much. The reviewer remarked that the project is pursuing the most beneficial way to reduce heat transfer from the cylinder while maximizing the benefit in terms of reduced fuel consumption and overall thermal management within the engine. The reviewer opined that the team's fundamental approach demonstrates a very high level of technical understanding of what needs to be done.

Reviewer 3:
The reviewer commented that there was a good approach to make a breakthrough in thermal barrier coating performance for controlling heat rejection. The team did a good job presenting needs across the entire cycle. The reviewer stated that there was a good comparison of conventional TBC during combustion and expansion. The approach to overcoming the stated barriers is promising.

Reviewer 4:
The reviewer noted that this approach is highly relevant to managing heat losses, one of the more elusive barriers to achieving engine efficiency close to theoretical and pragmatics limits. The modeling appears to

have captured the subtle effects of fuel trapping as well as thermal swings. The reviewer stated that the difficulties of sealing layers were experienced in prior work many years ago and pointed out that more references to previous approaches and experience would have made the presentation a little stronger. With the world-leading capabilities in materials and coatings, development and characterization at the DOE laboratories, the reviewer found it surprising that there are no laboratory partners in the project.

Reviewer 5:
The reviewer remarked that this is a high-risk project. Thermal barrier coatings have been pursued many times in the past and have had shortcomings, both with durability and with effectiveness. The reviewer asserted that the temperature-following coating with low heat capacity and low conductivity will solve many of the effectiveness problems, but the durability issues appear to be persistent. Using this material in the exhaust ports with the steel casting inserts appears to make sense, in the reviewer's opinion, as the nickel foil coating does not seem critical here. However, for the in-cylinder components (piston and valves), it appears to the reviewer that there needs to be further development on the coating and sealing processes. As a result, the reviewer suggested de-emphasizing the engine tests until the material coating and sealing can be improved to raise the confidence that engine tests will be more successful.

Reviewer 6:
The reviewer stated that this project concerns development of TBCs that will decrease heat loss from the combustion chamber of an engine as TBCs are a well-known technology for this purpose. The presentation noted that effective TBCs could increase fuel efficiency by 4%-8%, to which the reviewer suggested that the PI define what is meant by "fuel efficiency" as there are many possible definitions. The reviewer requested that a quantitative connection be established between a TBC metric and the 4%-8% target. When the PI notes that further improvements will enable 4%-8% efficiency gains and increase durability, the reviewer requested that the basis for this expectation be provided—the connection between a percentage gain and a TBC metric.

The PI notes the importance of thermal conductivity (k) as a metric of TBC, and this reviewer indicated that some data are reported in the presentation. Tasks are associated with measuring it as well that extend to 2019. The reviewer asked how k and porosity were measured as well as the accuracy of the measurements, and advised that error bars should be included in the measurements. The reviewer commented that the project as presented seemed not to state anything about thermal contact resistance (R_c), a critical parameter that will control TBC performance to an extent. The reviewer stated that some discussion of how R_c was measured, or will be measured, and how its effect was or will be incorporated in the modeling effort needs to be included in the project. Similarly, the reviewer remarked that adhesion measurements to assess bonding strength of the TBC seem also to be a critical parameter that will control performance. The importance of bonding was noted in the presentation though the metrology for measurement was not noted. The reviewer requested a discussion of how specifically a target efficiency value is quantitatively linked to any metric of a thermal barrier coating (k, R_c, thickness, bonding strength, etc.). The project seems to rely on such a link but the presentation was not quite clear on this point.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer indicated that the team has made good progress on a challenging, high-risk project.

Reviewer 2:
The reviewer noted that the project team has made good progress. The team has developed a thermal barrier with the desired thermal properties and demonstrated that the material can survive in the engine environment for short periods of time. The reviewer remarked that the challenges for the project team have been identified and courses of action have been identified to address them.

Reviewer 3:
The reviewer found that a lot of progress has been made with this technology, and clearly, the porous nickel shells are exciting for thermal barrier coating applications. The reviewer stated that many barriers remain on the bonding and sealing of the coating.

Reviewer 4:
The reviewer commented that the team has made significant progress on the development of the TBC insulation and did an excellent job showing current progress with coating issues. The reviewer found a good use of diagnostics to present finding on compaction. The modeling efforts tied to the project are well integrated and help explain observations. Despite this being the first year, the reviewer observed that the project has been reviewed and the team has made some notable accomplishments. The reviewer stated that more information about the experiments conducted and the amount of time and conditions the coated valves experienced could have been presented.

Reviewer 5:
The reviewer said that the project is highly focused on solving the problems of thermal properties and the necessary sealing layer. Modeling achievements are good progress and insightful. Nice innovations on materials brought praise from the reviewer. The project claims potential benefits in reducing engine knock, but the reviewer said that the explanation was not complete nor rigorous.

Reviewer 6:
Comments from the reviewer included statements about the reported progress on performance of TBCs. The importance of a surface sealing layer was noted. The project also tested pistons coated with TBCs where some success was noted. The reviewer stated that a failure mode appeared due to delamination or poor bonding of the coating to the piston. A solution was suggested based on improved brazing and adhesion. The reviewer mentioned a discussion of thermal modeling and the role of bonding. According to the reviewer, the presentation did not provide details regarding what was involved with the modeling effort.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer indicated that, while there is not a long list of collaborators, the parties involve are the right parties. HRL is leading the technology for the TBCs. GM is an engaged industrial partner that has the capability to bring the technology to market. Together, the reviewer opined that the team has the expertise to study and overcome barriers and move the technology forward.

Reviewer 2:
Being an industrial project, the reviewer commented that specific collaborators have been identified for their technical capabilities and they are actively engaged in the project.

Reviewer 3:
The reviewer pointed out that this project is a collaboration between HRL laboratories and GM, with GM being a subcontractor for engine testing. Other companies are being engaged.

Reviewer 4:
The complexity of this approach requires the right team, which seems to have been assembled. More information on the coordination across the teams could have been provided, but a very solid team. The reviewer remarked that the project milestone slide does show clear expectations of the primary team while collaboration with other partners is not yet clear.

Reviewer 5:
The role of GM is shown well enough in the schedule chart according to the reviewer, but other potential involvement by Federal Mogul, 3M, et al is not described. The reviewer posited that other partners with prior

experience in this approach and exceptional materials characterization capabilities (not to slight HRL or GM) are missing.

Reviewer 6:
The reviewer stated that the team seems appropriate, but the potential is there to address some of the challenges by involving another collaborator.

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 there was a very good summary of barriers to achieve goals and the future research is well-aligned to those goals. According to the reviewer, there was a very clear discussion of future research needed for both the sealing of the microsphere insulation and the bonding issues with the path for alternative piston material to facilitate bonding.

Reviewer 2:
The reviewer reiterated that the researchers have identified the principal challenges that need to be addressed and developed a future work plan to address them.

Reviewer 3:
The reviewer noted that the project team will be sourcing steel pistons to (temporarily) mitigate issues with bonding to aluminum. The reviewer said that this is a good idea that can permit demonstration of the benefits, if any. The reviewer suggested that the developers may consider modeling the benefits of changing the contents or the internal pressure of the spheres. During Q&A, the speaker mentioned examining higher pressure air to improve durability. The reviewer asked if there could be any heat exchange benefit to changing the gas or gas pressure (even considering pressure [P] below ambient).

Reviewer 4:
The reviewer said that the future work includes activities associated with fabrication of the TBCs, sealing, and examining different piston materials and coatings. However, the reviewer found no mention of thermal characterization of the TBCs, specifically regarding direct measurements of adhesion or bonding strength, R_c or thermal conductivity (some measurements were reported on the latter, though). The reviewer stressed that these measurements would seem essential to the project and should be a centerpiece of the PI's evaluation of the TBCs under investigation.

Reviewer 5:
The reviewer proposed that the impact of coatings on engine knock needs further investigation and explanation. Otherwise, the focus on resolving issues with the coating and seal layer are paramount and the focus of most future work.

Reviewer 6:
The reviewer noted that the majority of the future work focused on sealing and bonding, which is the correct path forward for this technology given that those are the main barriers to the technology. The reviewer believed there are other areas where future work is necessary, including understanding the impact that the added piston weight will have on friction (especially if steel pistons are required), developing a more detailed understanding of the impact of the barrier coating on high load performance (knock), understanding durability of knocking on TBC durability, and many more. These areas are all secondary to the proposed sealing and bonding activities in the proposed future work.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer responded yes, from a broad perspective.

Reviewer 2:
The reviewer noted that this project is well aligned with enabling DOE objectives.

Reviewer 3:
The reviewer remarked that this has been, and continues to be, an important area of engine development: enhanced in-cylinder thermal management.

Reviewer 4:
The reviewer stated that heat losses remain as an unresolved loss mechanism for internal combustion (IC) engines. Coatings are a possible, yet unperfected, approach.

Reviewer 5:
The reviewer commented that the development of this technology supports DOE's goal of enabling higher efficiency engines. TBCs are an enabling technology that can improve engine efficiency for a number of different combustion strategies under various conditions.

Reviewer 6:
The reviewer asserted that this is a high-risk, challenging enabling technology with potential for significant payoff if successful. This is an appropriate use of DOE resources for low TRL research.

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 resources and team appear to be sufficient for achieving the stated milestones.

Reviewer 2:
The reviewer found the program funding to be sufficient.

Reviewer 3:
The reviewer remarked that the project resources appear to be sufficient to accomplish the project goals.

Reviewer 4:
The reviewer noted that significant taxpayer resources are obligated, but a 50% cost-share from the partners show strong commitment to develop this technology.

Reviewer 5:
The reviewer observed that for work at an exploratory, early- to mid-TRL level and overall objectives, the resources are very adequate. A 50% cost share seems high for this type of project.

Reviewer 6:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Presentation Number: acs124
Presentation Title: SuperTruck II—PACCAR
Principal Investigator: Carl Hergart (PACCAR)

Presenter
Carl Hergart, PACCAR

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 and well-planned.

Reviewer 1:
The reviewer found the emphasis on recognizing and meeting customer needs while achieving program goals to be outstanding and noted that the program includes all the necessary subsystems like cab, trailer, engine, etc.

Reviewer 2:
The reviewer stated that the project's overall approach was nicely laid out and includes multiple areas where gains will be needed to achieve the program targets.

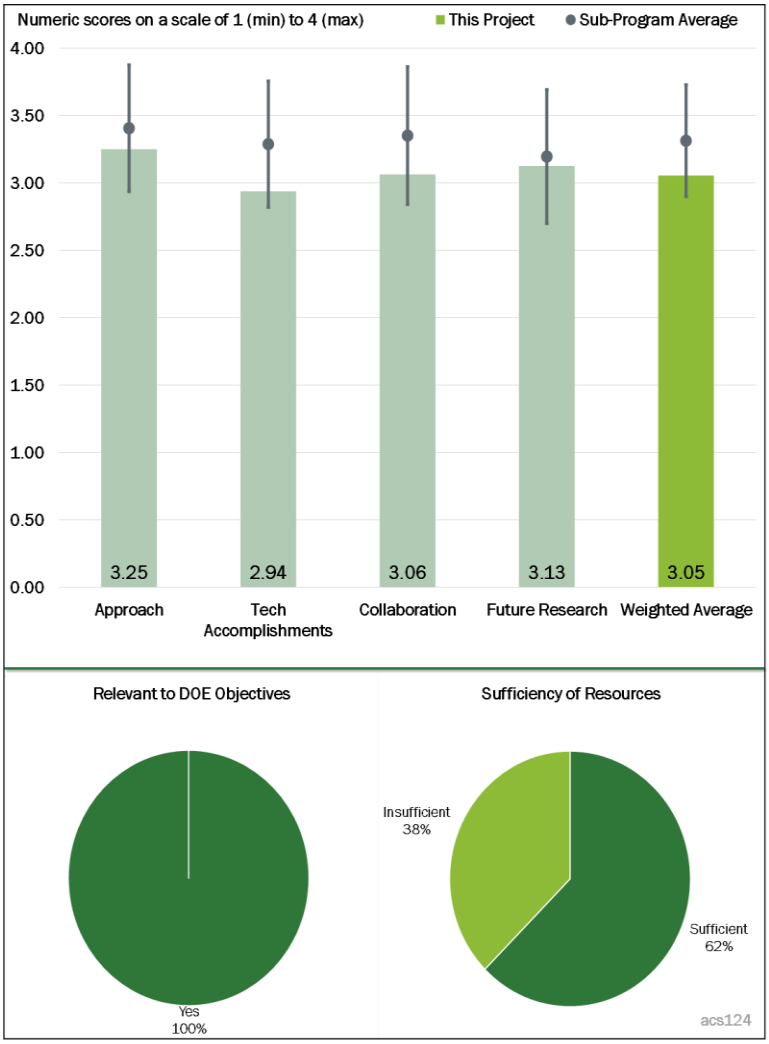

Figure 1-34 - Presentation Number: acs124 Presentation Title: SuperTruck II—PACCAR Principal Investigator: Carl Hergart (PACCAR)

Reviewer 3:
The reviewer remarked that the team is just getting started so it was somewhat difficult to evaluate.

Reviewer 4:
The reviewer commented that the project approach to achieving engine goals and vehicle freight efficiency goals appears well structured. The goals for the project are challenging, and as a mild criticism the technical approach does not have particularly innovative or high-risk elements. The hybrid powertrain assessment was well done.

Reviewer 5:
The reviewer noted that the project follows the other ST2 projects. This one appears to be lagging behind the others.

Reviewer 6:
The reviewer commented that the overall plans are good and fit well with what would be expected for a successful ST2 program. It is a little surprising that there was relatively little mention of route planning and other driver aid systems to increase efficiency. The reviewer remarked that there are also very few details on

how the engine improvements are to be realized. The goals for that work are pretty lofty and experience from ST1 would suggest that they are not as easy to achieve as they look.

Reviewer 7:
The reviewer stated that the proposed approach includes many key elements of technologies. However, nothing is mentioned on tires and axles, both of which are critical to the success of this program.

Reviewer 8:
The reviewer observed that because the project is being initiated in 2018, the technology approaches have been selected. This project is clearly benefitting from the projects that came before. The evaluation and incorporation of the various technologies into the mule vehicle seems to be well thought-out. It was clear to the reviewer that PACCAR no longer has its choice of partners. It is especially clear in the areas of aerodynamics, WHR suppliers, and tire improvement. The reviewer was especially disturbed by the lack of plans and tire improvement, which has been shown to a major contributor to BTE.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that there was a balanced plan to look at all technical areas for opportunities.

Reviewer 2:
The reviewer asserted that the accomplishments have been primarily limited to pre-design analyses to converge on component types.

Reviewer 3:
The reviewer said that the achievements to date are pretty well aligned with the time since the project started. There are no measureable improvements to be evaluated yet so the assessment is entirely based on the plans and early analysis of the technical path.

Reviewer 4:
The reviewer noted that this program is early, only 5% complete. The results are appropriate for this level of completion. The reviewer expects to see much more results as time passes.

Reviewer 5:
The reviewer stated that this project started less than 1 year ago, and the AMR material was submitted after only 6 months so the technical accomplishments reflect the early stages of the program. The reviewer found it difficult to evaluate so early in the program.

Reviewer 6:
The reviewer said that this project is in its early stages, and accomplishments are mostly from simulation and design considerations, which is understandable. The analysis of various options for hybridization is insightful. The reviewer found the incomplete selection of a drive cycle and lack of WHR supplier to be negative factors.

Reviewer 7:
The reviewer observed that no devices were developed or tested.

Reviewer 8:
Although the program started 1 year late compared to its competitors, the reviewer remarked that lack of WHR experience could be a show-stopper moving forward because there would be no other alternative to achieving 55% BTE without the help of WHR. The reviewer opined that the issue becomes even more severe due to a lack of overall program experience on such a large scale for the program because PACCAR was not part of the SuperTruck I program.

The reviewer emphasized that it is not clear why "novel air management concepts" are claimed in Slide 12 where there is no indication or even a clue of why this is "novel." A more detailed description would have been helpful to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Notwithstanding previous comments, the reviewer said that PACCAR has built a first-class team.

Reviewer 2:
According to the reviewer, PACCAR has done a nice job of assembling a total vehicle team including customer voices.

Reviewer 3:
The team looks good, but it was not clear to the reviewer how much collaboration and coordination across the team really exists from the work done so far.

Reviewer 4:
The reviewer commented that Slide 25 showed the major contributors nicely; however, on Slide 2, Mississippi State University was shown but was not mentioned in the presentation.

Reviewer 5:
The reviewer stated that project team had solid partners. Given some of concerns expressed during the presentation, the reviewer suggested that a ST2 customer focus group might help with the concern about "habitability challenges of drivers in aerodynamic trucks."

Reviewer 6:
The reviewer noted that the roles of the various partners are defined, but except for Kenworth their achievements and involvement to date are not evident in the presentation.

Reviewer 7:
The reviewer remarked that there does not appear to be an emissions aftertreatment partner.

Reviewer 8:
The reviewer was surprised to see no partner on tires, which are one of the most critical elements of this program.

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 the plan seems to be excellent. A wide range of technologies will be evaluated, with a suitable plan for downselecting a vehicle system.

Reviewer 2:
The reviewer commented that the research plan was laid out nicely and easy to understand.

Reviewer 3:
According to the reviewer, a good plan is emerging for this new project.

Reviewer 4:
The reviewer stated that the plans look good, but there are a number of risks that do not appear to have good mitigation strategies because PACCAR is new to the SuperTruck (ST) program and does not have the ST1 work to start from; this is going to require them to improve the engine and truck efficiency much faster than the other teams, which may prove to be a big challenge.

Reviewer 5:
The reviewer noted that most of the project is yet to be carried out. The project team still needs suppliers in tires and WHR. The team seems to have full recognition of the necessary next steps. The reviewer commented that the future research items were not very detailed or specific. A higher degree of new approaches or innovation would be an improvement.

Reviewer 6:
The reviewer observed limited description and details.

Reviewer 7:
The reviewer believed that the scale-up to real devices will be much harder than implied by the plan and wished the team good luck.

Reviewer 8:
Because of the program starting late and also because of no prior experience with such a large-scale program, it would have been helpful to the reviewer to have the team provide more detailed information on the proposed future research, which can help the reviewer to understand how much the developer can move the program forward with high confidence. However, the reviewer opined that Slides 18 and 24 fail to demonstrate knowledge and understanding of the challenges of this program.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that the project is clearly aligned with DOE objectives.

Reviewer 2:
The reviewer noted that ST2 seems to be very relevant to the DOE objectives.

Reviewer 3:
The reviewer stated that the project should lead to improved transportation efficiency and reduced petroleum use.

Reviewer 4:
The reviewer commented that improved engine efficiency and overall freight efficiency are directly aligned with the DOE objectives.

Reviewer 5:
The reviewer said that Class 8 fuel/freight efficiency improvement is critical to our country.

Reviewer 6:
The reviewer observed that this project, like the other SuperTruck awards, pushes the performance of integrated truck systems to higher levels. Cost-effectiveness and commercialization are welcome criteria. The reviewer urged the team to make sure the drive cycle ultimately selected is highly relevant.

Reviewer 7:
If it can deliver, the reviewer said that the project would reduce fuel consumption, which supports the overall DOE objectives.

Reviewer 8:
The reviewer pointed out that all the HD manufacturers must have the same chance to upgrade their technology. So far, the reviewer believed that PACCAR is disastrously behind the curve.

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 seem to be both necessary and sufficient for this large program.

Reviewer 2:
The reviewer found the resources to be aligned well with the amount of proposed work for this project.

Reviewer 3:
The reviewer stated that resources seem sufficient.

Reviewer 4:
The reviewer remarked that PACCAR and partners have capabilities to conduct R&D with the exception of emissions control technology.

Reviewer 5:
To catch up, the reviewer believed that PACCAR needs more resources.

Reviewer 6:
The reviewer expressed a little concern about basically achieving all of the ST1 and ST2 goals for only the ST2 budget, especially with systems like the WHR system that looks like it is going to need an outside partner not yet on the team.

Reviewer 7:
Whereas all of the SuperTruck projects appear adequately funded, individually, the reviewer questioned whether five teams (with the same goals) are really the most effective strategy to improve freight efficiency at the national scale.

Reviewer 8:
The reviewer commented that lack of experience makes the learning curve too steep. There may not be enough funding and time to allow the developer to use a trial-and-error approach to deliver the program goal. In addition, the reviewer stated that this program highly depends on WHR to achieve the program 55% BTE, but the developer has little or no experience on this matter, which makes this program highly risky.

Acronyms and Abbreviations

3-D	Three-dimensional
A/F	Air/fuel
ACEC	Advanced Combustion & Emissions Control
AEC	Advanced Engine Combustion
Al	Aluminum
Al_2O_3	Aluminum oxide (alumina)
AMFI	Additive-mixing fuel injection
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ANN	Artificial neural network
ARDL	Akron Rubber Development Laboratory
AVL-18a	Fuel for engine testing
Ba	Barium
Br	Bromine
BTE	Brake thermal efficiency
C_3H_6	Propene
C70	Fullerene molecule used as a conductor
CA50	Crank angle position at which 50% of heat is released
CD	Cylinder deactivation
Ce	Cerium
CeO_2	Cerium oxide (ceria)
CFD	Computational fluid dynamics
CFP	Capillary flow porometry
CH_4	Methane
CHA	Chabazite
CHT	Conjugate heat transfer
CI	Compression ignition, conversion inflection

Cl	Chlorine
CLEERS	Cross-cut Lean Exhaust Emissions Reduction Simulations
CNG	Compressed natural gas
CO	Carbon monoxide
CPU	Central processing unit
CRADA	Cooperative Research and Development Agreement
CRF	Combustion Research Facility
Crr	Coefficient of rolling resistance
CT	Computerized tomography
Cu	Copper
DEER	Directions in Engine-Efficiency and Emissions Research
DEF	Diesel-exhaust fluid (urea)
DI	Direct-injection
DOE	U.S. Department of Energy
DPF	Diesel particulate filter
DSF	Dynamic Skip Fire
E10	10% ethanol content gasoline
E85	85% ethanol content gasoline
ECN	Engine Combustion Network
ECU	Engine control unit
EGR	Exhaust gas recirculation
EHN	Ethylhexyl nitrate
ELSA	Euler-Lagrange spray atomization
EMS	Energy management system
EPA	U.S. Environmental Protection Agency
EPR	Electron Paramagnetic Resonance
EXAFS	Extended X-ray absorption fine structure
FACE	Fuels for advanced combustion

FCA	Fiat Chrysler Automobiles
FTIR	Fourier transform infrared
FTP	Federal Test Procedure
FY	Fiscal Year
GCI	Gasoline compression ignition
GDI	Gasoline direct injection
GM	General Motors
GPF	Gasoline particulate filter
HC	Hydrocarbon
HCl	Hydrochloric acid
HD	Heavy-duty
HDD	Heavy-duty diesel
HPC	High-performance computing
HRR	Heat-release rate
HTA	Hydrothermal aging
IC	Internal combustion
ICE	Internal combustion engine
IR	Infrared
JMI	Johnson Matthey Inc.
k	Thermal conductivity
LD	Light-duty
LES	Large eddy simulation
LESI	Lagrangian-Eulerian spark ignition
LLNL	Lawrence Livermore National Laboratory
LT	Low-temperature
LTAT	Low-temperature aftertreatment
LTC	Low-temperature combustion
LTGC	Low-temperature gasoline combustion

mg	Milligram
MIT	Massachusetts Institute of Technology
Mn	Manganese
MOU	Memorandum of Understanding
NH_3	Ammonia
nm	Manometer
NO_x	Oxides of nitrogen
O_2	Oxygen
OBD	On-board diagnostics
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
P	Pressure
PAH	Polycyclic aromatic hydrocarbon
Pd	Palladium
PGM	Platinum group metals
PI	Principal Investigator
PM	Particulate matter
PMI	Particulate matter index
PN	Particle number
PNA	Passive NO_X adsorber
PNNL	Pacific Northwest National Laboratory
Pt	Platinum
Q&A	Question and answer
R&D	Research and development
R_c	Thermal contact resistance
RCM	Rapid compression machine
RD587	88-octane research gasoline
rpm	Revolutions per minute

s	Second
S	Sulfur
SAE	Society of Automotive Engineers
SCO	Selective catalytic oxidation
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
Si	Silicon
SI	Spark ignition
SNL	Sandia National Laboratories
ST	SuperTruck
ST1	SuperTruck I
ST2	SuperTruck II
T50	Temperature at which 50% conversion occurs
T90	Temperature at which 90% conversion occurs
TBC	Thermal barrier coating
TCO	Total cost of ownership
TJI	Turbulent jet ignition
TPI	Transient plasma ignition; tuned port injection
TRL	Technology readiness level
TWC	Three-way catalyst
U.S. DRIVE	United States Driving Research for Innovation for Vehicle efficiency and Energy sustainability
USCAR	United States Council for Automotive Research
UW	University of Washington
UW	University of Wisconsin – Madison
VERIFI	Virtual Engine Research Institute and Fuels Initiative
VTO	Vehicle Technologies Office
WHR	Waste heat recovery

Zero-RK	Zero-order reaction kinetics
Zr	Zirconium
ZrO_2	Zirconium dioxide (zirconia)