1. Advanced Combustion Engines

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Advanced Combustion Engines (ACE) subprogram supports research and development (R&D) necessary for industry to develop efficient engines that can utilize renewable fuels, such as advanced biofuels, hydrogen, and e-fuels, to reduce GHG emissions and achieve a net-zero economy by 2050, all while creating good paying jobs with the free and fair chance to join a union and bargain collectively. Internal combustion engines will continue to be an important power source for medium- and heavy-duty onroad trucks and off-road vehicles including construction, agriculture and forestry, and rail and marine, during the next several decades. Increasing their efficiency and reducing GHG and criteria emissions will ensure that the clean energy economy benefits all Americans. Optimization of high efficiency engines and emission control systems, integration of hybrid powertrains, and utilization of renewable fuels has the potential to improve heavy-duty engine efficiency.

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.

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
ace015	Stretch Efficiency for Combustion Engines: Exploiting New High-Dilution Combustion Regimes	Jim Szybist (ORNL)	1-7	3.50	3.40	3.20	3.20	**3.38**
ace022	Joint Development and Coordination of Emissions Control Data and Models (Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Analysis and Coordination)	Josh Pihl (ORNL)	1-12	3.83	3.33	4.00	3.33	**3.54**
ace023	Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS): Fundamentals and Coordination	Yong Wang (PNNL)	1-16	3.17	3.00	3.33	3.33	**3.13**
ace027	Fundamental Understanding of Copper-Zeolite Selective Catalytic Reduction (SCR) Catalyst Aging Mechanism (Cummins CRADA)	Feng Gao (PNNL)	1-18	3.60	3.50	3.70	3.20	**3.51**
ace032	Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): Nitrogen Oxide Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems	William Partridge (ORNL)	1-22	3.00	3.00	3.00	2.88	**2.98**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace033	Emission Control for Lean Gasoline Engines	Vitaly Prikhodko (ORNL)	1-26	3.50	3.50	3.50	3.17	**3.46**
ace056	Platinum Group Metals (PGM) Reduction in Three-Way Catalysts (TWCs)	Yong Wang (PNNL)	1-29	3.00	3.13	3.00	2.88	**3.05**
ace085	Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization	Todd Toops (ORNL)	1-33	3.50	3.33	3.50	3.17	**3.38**
ace100	Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2	Darek Villeneuve (Daimler Trucks North AmerIca)	1-35	3.42	3.33	3.42	3.17	**3.34**
ace101	Volvo SuperTruck 2: Pathway to Cost-Effective Commercialized Freight Efficiency	Pascal Amar (Volvo Trucks North America)	1-40	3.00	2.67	3.00	2.75	**2.80**
ace102	Cummins-Peterbilt SuperTruck 2	Jon Dickson (Cummins-Peterbilt)	1-46	3.58	3.58	3.50	3.50	**3.56**
ace103	Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck	Russell Zukouski (Navistar)	1-50	3.08	3.08	3.17	3.00	**3.08**
ace118	Advanced Nitrogen Oxide Storage	Janos Szanyi (PNNL)	1-55	2.88	2.75	3.00	3.13	**2.86**
ace119	Advanced Multi-Functional Diesel Particulate Filters (Deer and Company)	Ken Rappe (PNNL)	1-59	3.33	3.17	3.50	3.17	**3.25**
ace124	SuperTruck 2 - PACCAR	Maarten Meijer (PACCAR)	1-62	3.08	3.17	3.17	3.08	**3.14**
ace128	Reduced Precious Metal Catalysts for Methane and Nitrogen Oxide Emission Control of Natural Gas Vehicles	Michael Harold (University of Houston)	1-67	3.50	3.38	3.25	3.13	**3.36**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace133	Next-Generation Heavy-Duty Powertrains	Scott Curran (ORNL)	1-70	3.50	3.63	4.00	3.33	**3.60**
ace138	Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium	Matthew McNenly (LLNL)	1-74	3.75	3.58	3.83	3.25	**3.61**
ace139	Chemical Kinetic Models for Surrogate Fuels	Scott Wagnon (LLNL)	1-78	3.60	3.40	3.70	3.50	**3.50**
ace140	Accelerated Chemistry and Transport for Engine Simulations	Russell Whitesides (LLNL)	1-83	3.38	3.75	3.38	3.00	**3.52**
ace141	Advanced Ignition Barriers Research	Isaac Ekoto (SNL)	1-86	3.38	3.25	3.38	3.38	**3.31**
ace142	Development and Validation of Predictive Ignition Models	Riccardo Scarcelli (ANL)	1-90	3.50	3.25	3.38	3.25	**3.33**
ace143	Fuel Injection and Spray Research	Chris Powell (ANL)	1-93	3.60	3.40	3.40	3.40	**3.45**
ace144	Spray Wall Interactions	Lyle Pickett (SNL)	1-98	3.80	3.40	3.60	3.50	**3.54**
ace145	Cold Start Modeling and Experiments for Emissions Reduction	K. Dean Edwards (ORNL)	1-102	3.50	3.50	3.38	3.50	**3.48**
ace146	Direct Numerical Simulation (DNS) and High-Fidelity Large Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes	Muhsin Ameen (ANL)	1-106	3.25	3.38	3.13	3.25	**3.30**
ace147	Mitigation of Abnormal Combustion	Derek Splitter (ORNL)	1-109	3.40	3.30	3.10	3.30	**3.30**
ace153	Chemistry of Cold-Start Emissions and Impact of Emissions Control	Melanie Moses-DeBusk (ORNL)	1-113	3.75	3.50	3.50	3.50	**3.56**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace155	Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications	Qigui Wang (General Motors, LLC)	1-117	3.42	3.42	3.17	3.25	**3.36**
ace156	Next-Generation, High-Efficiency Boosted Engine Development	Michael Shelby (Ford Motor Company)	1-121	3.63	3.38	3.38	3.38	**3.44**
ace158	Slashing Platinum Group Metals (PGM) in Catalytic Converters: An Atoms-to-Autos Approach	Wei Li (General Motors, LLC)	1-125	3.00	2.75	3.25	3.25	**2.94**
ace159	Reduced Cost and Complexity for Off Highway Aftertreatment	Ken Rappe (PNNL)	1-128	2.67	2.67	3.00	2.67	**2.71**
ace160	Optimization and Evaluation of Energy Savings for Connected and Autonomous Off-Road Vehicles	Zongxuan Sun (University of Minnesota)	1-131	3.10	3.00	3.40	3.20	**3.10**
ace161	New Approach for Increasing Efficiency of Agricultural Tractors and Implements	Andrea Vacca (Purdue University)	1-136	3.33	3.17	3.33	3.33	**3.25**
ace162	Improved Efficiency of Off-Road Material Handling Equipment through Electrification	Jeremy Worm (MTU)	1-139	2.67	2.17	2.67	2.83	**2.44**
ace163	Ducted Fuel Injection and Cooled Spray Technologies for Particulate Control in Heavy-Duty Diesel Engines	Adam Klingbel (Wabtec)	1-142	3.38	3.38	3.50	3.38	**3.39**
ace164	Improving Efficiency of Off-Road Vehicles by Novel Integration of Electric Machines and Advanced Combustion Engines	Sage Kokjohn (University of Wisconsin)	1-146	3.75	3.75	3.50	3.63	**3.70**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace165	Advancing Simulation Tools for Heavy Duty Engine Combustion Using X-ray Diagnostics	Gina Magnotti (ANL)	1-151	3.50	3.40	3.60	3.50	**3.46**
ace166	New Two-Cylinder Prototype Demonstration and Concept Design of a Next Generation Class 3-6 Opposed Piston Engine	Fabien Redon (Achates Power, Inc.)	1-156	2.50	2.80	3.30	2.80	**2.79**
ace167	Spray/Flow Interaction in Engines	Roberto Torelli (ANL)	1-161	3.60	3.40	3.50	3.10	**3.43**
ace168	Soot Modeling and Experiments	Julien Manin (SNL)	1-164	3.40	3.40	3.50	3.50	**3.43**
ace169	Greatly Reduced Vehicle Platinum Group Metals (PGM) Contant Using Engineered, Highly Dispersed Precious Metal Catalysts	Yong Wang (Washington State University)	1-168	3.00	2.75	3.25	3.00	**2.91**
Overall Average				**3.34**	**3.24**	**3.37**	**3.22**	**3.28**

Presentation Number: ace015
Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New High-Dilution Combustion Regimes
Principal Investigator: Jim Szybist (ORNL)

Presenter

Jim Szybist, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

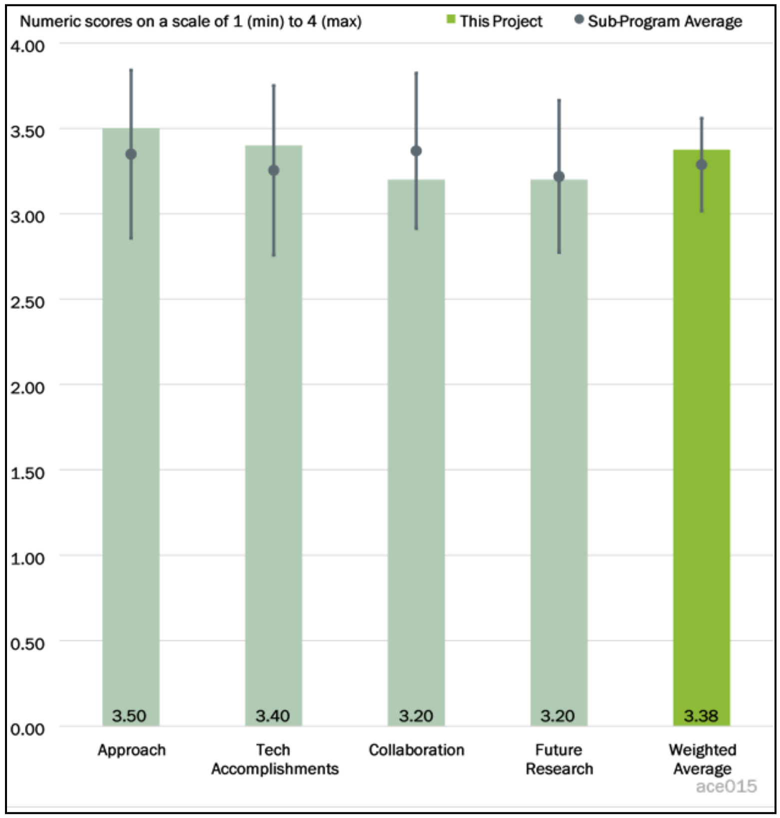

Figure 1-1 - Presentation Number: ace015 Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New High-Dilution Combustion Regimes Principal Investigator: Jim Szybist (ORNL)

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 said that it is a well-managed project from a technical point of view.

Reviewer 2:

The reviewer stated the approach is very interesting—using one cylinder of a four-cylinder engine to create reformate that allows for improved molar expansion ratio (MER) in the pursuit of higher efficiency and potentially lower oxides of nitrogen (NO_x) emissions. This project is exploring the thermodynamic tradeoff between potentially improved Second Law of Thermodynamics efficiency versus heat transfer and other more conventional efficiency gains. The reviewer also stated the question will be whether the additional hardware and controls costs will be worth the potentially higher efficiency.

Reviewer 3:

The reviewer commented the combined approach using thermodynamics principles, engine experimentation, and modeling together is excellent. The focus on stoichiometric operation makes the very concept relevant for emissions technology.

Reviewer 4:

The reviewer said the work is well designed and well planned for the key objectives identified. However, it is less clear that the key overall barriers to advancement of the reforming concept are being addressed by the specific study elements.

Reviewer 5:

The reviewer commented the insight on MER and efficiency for a project with a modest (relative to other projects) $150,000 budget. The reviewer stated barriers to commercialization remain.

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 the MER investigation is useful. The increased MER effect has been known for decades, but seldom reduced to practice. However, it would be disappointing if that were all this project achieved. The reviewer suggested there must be other stoichiometric combustion phenomena that can be investigated.

Reviewer 2:

The reviewer stated the project is on track to the stated goals.

Reviewer 3:

While the Principal Investigator (PI) are not expected to devise the optimal control strategy for this concept, the reviewer indicated it would be nice to discuss the strategy of lowest load operation (where the heavily reformate-dilute combustion actually is lost relative to baseline). The reviewer asked if the dilution system can be easily shut off at those load points or if the reforming catalysts will cool off too much. The reviewer also inquired about the operability temperatures required for the reformate catalysts to operate.

Reviewer 4:

The reviewer reported the 2020 milestone was completed. While the work is on track, the 2021 milestone is an end-of-year milestone, and the meat of the project progress is still to be completed. The reviewer noted the project does not have clear performance indicators, making it hard to judge overall project progress on a development arc.

Reviewer 5:

The reviewer acknowledged that the PI has taken previous comments and incorporated them into the current work. The engine showed the ability to achieve some efficiency gains, as well as an opportunity to reduce the engine-out NO_x using the reformer cylinder. However, the reviewer stated the current configuration is still pretty far from resembling production hardware, particularly in the air-handling system.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented there were good results from collaboration. However, most of the end products of the work seem to be technical papers, rather than any sort of technology transfer to original equipment manufacturers (OEM) or suppliers. The reviewer also stated with the internal combustion (IC) engine under significant threat, it seemed there is insufficient time for the old engine-development model to work, where advances took a decade to see commercialization.

Reviewer 2:

The reviewer stated that adding a partner to assist with the reformer catalyst was an excellent idea. The communication and collaboration between project partners appeared to be effective, which enabled technical progress to be made. The reviewer stated also it would be helpful in the future to potentially have either an OEM or a turbocharger supplier work closely with this project.

Reviewer 3:

The reviewer commented standard collaboration avenues (Advanced Engine Combustion [AEC]) have been supplemented with additional industry (Precision Combustion Inc. [PCI]) and university (Ghent) collaborations.

Reviewer 4:

The reviewer stated there are evident technical collaborations between the project team and researchers from an academic institution through a joint publication and aligned research and catalyst suppliers for catalyst development. The catalyst development scope in the partnership, however, is not as clear. The reviewer also stated these partners were involved in the project since its inception, and limited discussion is focused on catalyst development, making it unclear whether this is an active effort or continued use of catalysts developed early in the project. It is also challenging that so many of the other collaborations noted focus on discussion. While it is encouraging that the project team is actively soliciting feedback on opportunities and barriers, the lack of an OEM partner backing the technology project raises concerns that it is pursuing a technology not likely to see uptake for commercial development.

Reviewer 5:

The reviewer stated there could have been better OEM involvement. Alignment with an OEM for commercialization should be a priority for this and future projects considering the pressures placed on the future relevance of the internal combustion engine (ICE).

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said that plans to combine this technology with flame speed enhancing devices (pre-chambers [PCs], etc.) are an excellent avenue.

Reviewer 2:

The reviewer stated future work looks to address the efficiency tradeoffs that were discovered in the first portions of the work, particularly as pertains to exhaust gas recirculation (EGR). The prosed idea to explore the opportunity for studying any sulfur (S) poisoning of the reformer catalyst is also very sound. The reviewer stated it would be useful to see some more work done on examining how the Second Law efficiency tradeoffs can influence potential engine OEM decision-making regarding incorporating this strategy in a future product. It makes sense to look at low carbon and net-zero carbon fuel possibilities as well.

Reviewer 3:

The reviewer said the future research seems to be more of the same. How does this work relate to other dedicated EGR projects or to other thermo-chemical recuperation systems or projects?

Reviewer 4:

The reviewer said the proposed future work to address the identified “Remaining Barrier 1” focused on the efficiency tradeoffs is well aligned with addressing open questions associated with this technology. Understanding the balance of efficiency tradeoffs is important, as the project team notes, to aligning future development efforts appropriately. The reviewer said the second workstream, focused on the impact of fuel-borne (S on catalyst efficacy, is a lower priority. Recognizing that prior-year reviewers have highlighted this as an area to focus, it does not seem as critical a barrier to adoption of the technology. Given the scale of system complexity compared to a conventional spark ignition (SI) engine, the reviewer stated that delivering sufficient efficiency opportunities to justify the added cost and complexity seems to be the primary barrier, more so than catalyst durability The focus on MER impacts, "Remaining Barrier 3," is interesting from a scientific perspective, but is fundamental focused; it is less clear to the reviewer how this advances the overall program.

The reviewer stated the proposed future work does include a decision point, with respect to the work focus as determined by the work on "Remaining Barrier 1." However, it would be good to see more aggressive decision points or go/no-go milestones incorporated to reflect the overall technology development. The reviewer stated this has been a long-running program, with work extending back well before the current iteration started in the 2019 lab call.

An additional technical direction to consider is whether the reformer process can be used to leverage lower octane fuels at conditions relevant to vehicle drive cycles. The reviewer said it appears high load conditions, where the knock mitigation is most valued, may be limited by air- system capabilities. Reducing the target load range may align the reformer capabilities for improving knock resistance with the engine hardware constraints.

Reviewer 5:

The reviewer stated these are reasonable goals considering project will end in Fiscal Year (FY) 2021.

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

Reviewer 1:

The reviewer said this project directly addresses the improvement of SI engine efficiency and emissions compliance.

Reviewer 2:

The reviewer stated the researchers draw clear correlations between the research areas and U.S. Department of Energy (DOE) identified barriers and objectives.

Reviewer 3:

The reviewer stated advancing the IC engine is still a useful endeavor and asked about low- or zero-carbon fuels, including biofuels and/or hydrogen (H_2).

Reviewer 4:

The reviewer commented the project supports overall DOE objectives of engine efficiency improvements and technologies to advance IC engine development. With the recent shifts in DOE objectives toward development supporting harder-to-electrify sectors, it may not remain well aligned in its current form.

Reviewer 5:

The reviewer stated that, for the project to remain relevant, a strong link to commercialization is needed for this and any future endeavors.

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 this project seems to be proceeding adequately on the allocated budget.

Reviewer 2:

The reviewer stated resources appear sufficient, unless switching to PC work will incur large costs.

Reviewer 3:

The reviewer commented that this is great fundamental research for a modest budget.

Reviewer 4:

The reviewer said the level of work and results are well aligned with the relatively low funding level. That said, the challenge is whether the technology being explored has high potential for a meaningful impact on engine technology evolution, and if there is potential to transition to higher Technology Readiness Level (TRL) commercial development. The reviewer also said if it does, then the project could benefit not only from more resources, but also strong milestones and go/no-go decision points. If the technology does not have the potential, or the OEM interest, then even a low level of funding is excessive, and the project should probably stop. The low funding level allows the research to trundle along without necessarily significant criticism or significant impact.

Reviewer 5:

The reviewer commented the last 2 years provided little more than caretaker funds for this project. It needs more resources if there is to be any substantial progress made toward achieving the goals.

Presentation Number: ace022
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 (ORNL)

Presenter

Josh Pihl, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

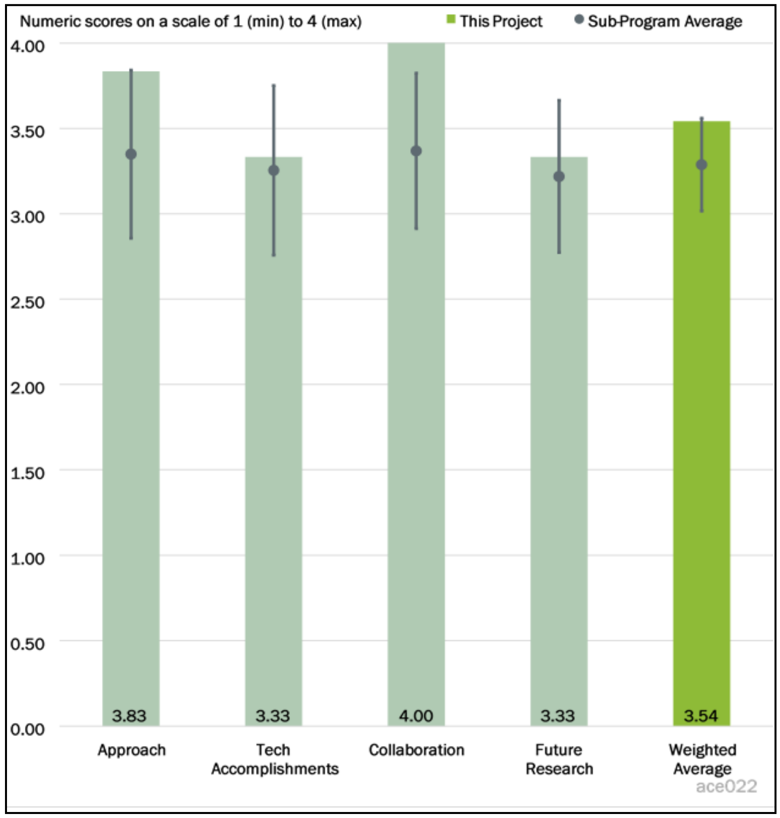

Figure 1-2 - Presentation Number: ace022 Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Analysis and Coordination) Principal Investigator: Josh Pihl (ORNL)

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 Crosscut Lean Exhaust Emissions Reduction Simulations (CLEERS) does a great job of aligning practical experiments with analytical models for critical aftertreatment devices. The annual workshop involves OEMs, suppliers, universities, and national laboratories. The reviewer stated last year's free, virtual format was well done and well received, allowing more participants than usual. The annual survey helps set priorities for the projects. The reviewer stated abandoning polynuclear aromatics (PNA) is the right direction. The hydrocarbon trap (HCT) is very worthy of further investigation and modeling toward future emission standards. The reviewer stated applying the selective catalytic reduction (SCR) model to longer mileages will be helpful for medium-duty (MD) and heavy-duty (HD) diesel.

Reviewer 2:

The reviewer commented that the project team did a great job coordinating the collaboration activities, including the annual CLEERS conference (whether virtual or in person) and the teleconferences. It is good that the project curtailed the work on NO_x traps and increased the research on HC traps. The reviewer commented that CLEERS at Oak Ridge National Laboratory (ORNL) continues to be a good blend of coordination activities and technical research.

Reviewer 3:

The reviewer said wrapping up PNA work is good progress since the industry survey indicated SCR and ammonia oxidation (AMOX) as the topics of interest. The aging effect of SCR is a highly important topic to be focused on.

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 progress was made on the Langmuir HC trap model. The SCR NO_x reduction and ammonia (NH_3) storage model was extended to represent longer mileages. Models were used only to predict reactor data. The reviewer said predicting vehicle data is much more difficult.

Reviewer 2:

The reviewer observed a very nice study on the adsorption of different HCs on the uncatalyzed zeolite beta (BEA) formulation using the single-site Langmuir isotherm. Also, there is a very nice fit of the NH_3 storage capacity of the copper (Cu)/aluminosilicate zeolite (SSZ-13) catalyst as a function of the storage temperature, aging temperature, water (H_2O) concentration, and NH_3 concentration using the three-site model. The reviewer gave kudos for investigating the NO_x conversion of the Cu/SSZ-13 catalyst with the pre-adsorbed NH_3 at different temperatures and aging conditions.

Reviewer 3:

The reviewer asserted that excellent progress has been made in the last year, with all the uncertainties that revolved around the pandemic. The virtual CLEERS workshop is a highlight of the accomplishments in 2020. The results related to SCR aging are very promising, especially the drop in low-temperature NH_3 storage with increasing age.

The reviewer inquired if there is any research on nitrous oxide (N_2O) generation pathways from SCR being researched. Since greenhouse gas (GHG) emissions are becoming critical, N_2O pathways from SCR may start becoming critical.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration and coordination are where CLEERS delivers on its mission. The reviewer noted that the workshop involved 250 people from industry, academia, and national laboratories. Monthly audios are also well attended. Presentations shared are on very timely topics.

Reviewer 2:

CLEERS is very effective for promoting collaboration among industry researchers on vehicle emission controls. According to the reviewer, the CLEERS conference and monthly teleconferences are excellent forums for the sharing of pre-competitive emissions data from different companies and institutions. The priorities survey also highlights the emission control topics that currently need to be prioritized. CLEERS at ORNL has good collaboration with the University of Virginia, Johnson Matthey, Pacific Northwest National Laboratory (PNNL), the Advanced Combustion and Emissions Control (ACEC) tech team, and the advanced engine crosscut team.

Reviewer 3:

The presentation shows a large collaborative effort between industry, academia, and national laboratories; the reviewer asserted that it would be interesting to group the collaborators according to their contributions.

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

Reviewer 1:

Since the industry may be considering dual SCR with an iron (Fe) zeolite close to the engine and a copper zeolite after the diesel particulate filter (DPF), the reviewer wanted to know whether the SCR-related research would be focused on the Fe zeolite catalyst as well. Also, will the SCR-coated DPF be a topic of research since off-road applications may consider this pathway?

Reviewer 2:

Aged SCR performance at higher mileages is worthy of further investigation. The reviewer encouraged the team to continue using the annual survey to set priorities for the work. The HC trap will be critical for gasoline vehicles to meet Super Ultra-Low Emissions Vehicle (SULEV)20/30. PNA is not durable and there is no business case for palladium (Pd) as a NO_x storage media anyway.

Reviewer 3:

The reviewer indicated that the collaboration and coordination activities should definitely be continued with the annual CLEERS conference and the teleconferences. The HCT work needs to be expanded to include catalyzed HCTs (with Pd and/or platinum [Pt]) so the stored HC species oxidation can be studied. The reviewer also remarked that there is a need to assess methods to introduce oxygen (e.g., with oxygen storage capacity [OSC] and air injection) so the adsorbed HCs can be oxidized on stoichiometric engines where there is no excess oxygen. The effects of different aging conditions (rich, stoichiometric, or lean) on the HCT would be helpful (similar to the work performed on the SCR catalyst for the passive SCR lean-burn project).

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

Reviewer 1:

The reviewer commented the project supports the overall DOE objectives of developing fundamental simulations for an aftertreatment system that can lower NO_x emissions during low-temperature operation as well as lower carbon dioxide (CO_2) emissions. Lowering fuel consumption will invariably result in lower exhaust thermal energy, and this research project supports the goal of simultaneously lowering tailpipe emissions of NO_x as well as CO_2.

Reviewer 2:

The reviewer said the CLEERS work supports fuel efficiency and energy independence through improved understanding of aftertreatment devices.

Reviewer 3:

The reviewer stated CLEERS conferences and telecoms provide a good forum for sharing technical data with peers from other companies and thereby are helpful for promoting pre-competitive collaboration. Studying emission control technologies that will help fuel-efficient engines go into production while satisfying the appropriate emission standards will help DOE achieve its goal of reducing dependence on foreign oil.

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 there is a wealth of computing and experimental bench testing resources with ORNL as well as their collaborators to conduct this project.

Reviewer 2:

The reviewer stated resources appear to be adequate for now, although there might be a need for more resources for experimental research in order to expand the HCT work to include oxygen addition, HC oxidation, and the effects of aging on the HCT.

Reviewer 3:

The reviewer said current resources appear to be sufficient. Future resources are a question for any area that supports ICEs, although it is believed by many that ICEs will continue for several more decades, and higher efficiency emission controls will be needed more than ever.

Presentation Number: ace023
Presentation Title: Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS): Fundamentals and Coordination
Principal Investigator: Yong Wang (PNNL)

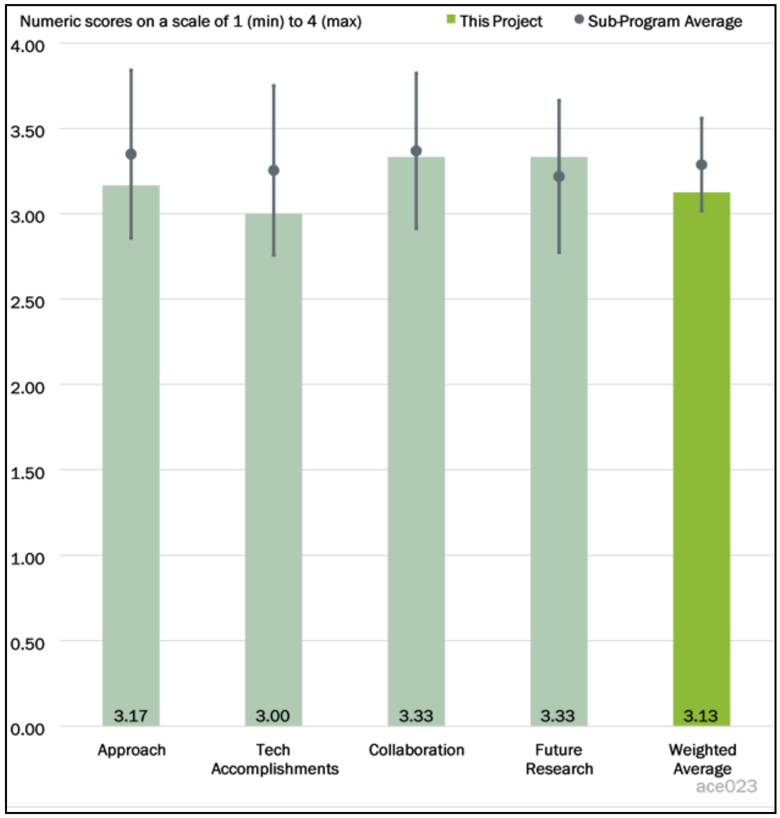

Figure 1-3 - Presentation Number: ace023 Presentation Title: Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS): Fundamentals and Coordination Principal Investigator: Yong Wang (PNNL)

Presenter

Yong Wang, PNNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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:

PNNL made good use of its expertise in fundamental science to study and develop emission control catalysts. The work on single-atom catalysts with Cu could be beneficial for reducing platinum group metals (PGM) loadings in catalytic converters. The reviewer observed that developing new tools such as electron paramagnetic resonance (EPR) spectroscopy for examining aged SCR catalysts can be useful for understanding the deactivation of current catalysts and hopefully will lead to catalysts with improved thermal durability to meet the increased mileage requirements.

Reviewer 2:

The reviewer stated the approach to address industry priorities is excellent, since ultimately this fundamental work should cater toward the greater goal of developing cleaner exhaust systems in production vehicles.

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 good work on using EPR for characterizing the aged SCR catalysts and an interesting study on the effects of S poisoning and desulfation on the single-atom Cu/cerium (Ce) catalyst under lean conditions. Nice job on adding manganese (Mn)-cerium (Ce) to the SCR catalyst to increase the NO_2 formation, thereby improving the low-temperature activity of the catalyst.

Reviewer 2:

The research team accomplished many of their key milestones and addressed many of the comments from previous year reviews, according to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

PNNL demonstrated good collaboration with General Motors (GM), the University of New Mexico, and Washington State University on the single-atom catalysts. The reviewer noted that PNNL also collaborates with ORNL on the annual CLEERS conference.

Reviewer 2:

The reviewer said collaboration with the industry helped the overall progress of the project.

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

Reviewer 1:

The reviewer asserted that there were several needs to assess and investigate: single-atom catalysts (SAC) Cu catalysts for stoichiometric applications; promising catalysts at higher temperatures (e.g., 900°C and 950°C) for engines operating at stoichiometry; and S-poisoning and desulfations on the MnCe-modified SCR catalyst because Mn is difficult to disulfate and S is known to inhibit the low-temperature activity of SCR catalysts.

Reviewer 2:

The focus on SCR-filters was very interesting to the reviewer, and it is good to see the project team has proposed this idea for future work.

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

Reviewer 1:

The reviewer said PNNL is developing catalysts for low-temperature operation, which will be needed to meet the Tier 3 Bin 3 emission standards with future fuel-efficient engines that generate lower exhaust temperatures. The project team is also working on catalyst technologies (e.g., SAC Cu) that can reduce PGM use, which is critical given today's market prices for Pd and rhodium (Rh).

Reviewer 2:

Understanding the chemical kinetics and the failure mechanisms of modern aftertreatment systems are highly critical, according to the reviewer. This best practice supports the overall DOE objective of lowering energy consumption from transportation while lowering tailpipe emissions.

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 PNNL and its industry collaborators have sufficient resources to complete current and future milestones.

Reviewer 2:

Resources appeared to be sufficient to the reviewer for the current workload.

Presentation Number: ace027
Presentation Title: Fundamental Understanding of Copper-Zeolite Selective Catalytic Reduction (SCR) Catalyst Aging Mechanism (Cummins CRADA)
Principal Investigator: Feng Gao (PNNL)

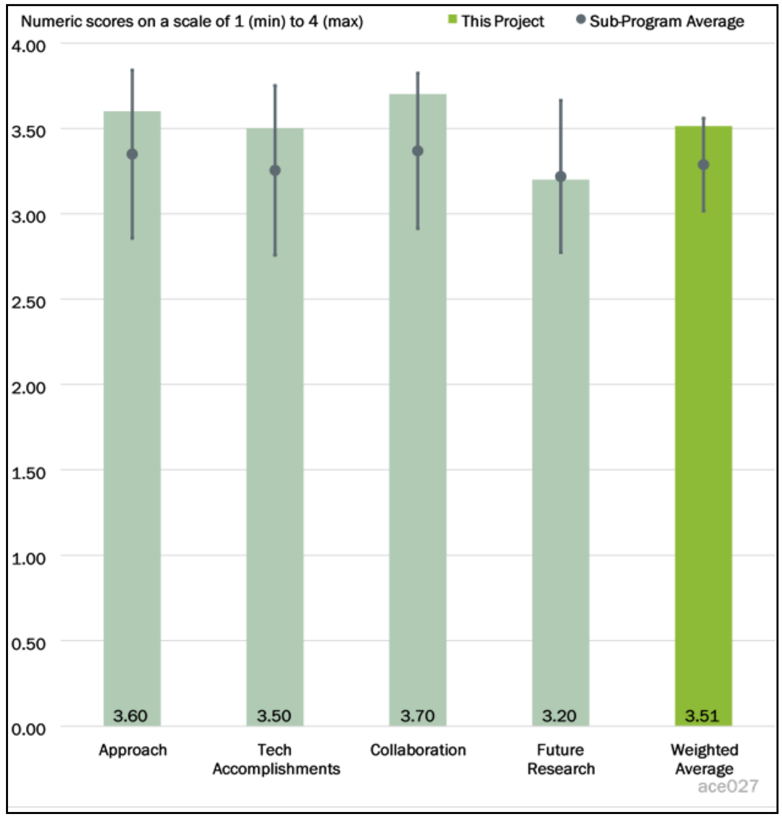

Figure 1-4 - Presentation Number: ace027 Presentation Title: Fundamental Understanding of Copper-Zeolite Selective Catalytic Reduction (SCR) Catalyst Aging Mechanism (Cummins CRADA) Principal Investigator: Feng Gao (PNNL)

Presenter

Feng Gao, PNNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 this is a methodical approach with four key milestones (two of which have been completed). It leverages PNNL's core competencies developed as part of CLEERS research and Cummins' lab- and field-aging specimen characterization to generate models that describe the SCR performance degradation.

Reviewer 2:

The approach to this work is sound and makes good use of PNNL's strength in catalyst characterization and tool development. The reviewer hoped that, by determining the mechanism for increased aging in field-age versus lab-aged samples, a technique for mitigating this increase can be developed.

Reviewer 3:

This reviewer commented that the set of tools selected turned out to be very appropriate for identifying the difference in aging field-aged and lab-aged samples.

Reviewer 4:

SCR catalyst aging directly affects the NO_x conversions in use, and the state of Cu active species is a critical issue that needs to be understood. Therefore, it made sense to the reviewer to use various characterization tools to probe the nature and state of the Cu species, including the effect of the poison species (sulfur or others). In addition, zeolite structure and acidity may also affect the catalyst NO_x conversion and thus should be examined as well. Because additional poison was suspected to be the reason for the discrepancy between field- and lab-aged catalysts, elemental analysis should be carried out on the field-aged catalysts.

Reviewer 5:

The reviewer noted that this project takes aim at reducing the gap between real-world, aged SCR catalysts and lab-aged catalysts. The researchers will use a multitude of characterization techniques to compare the field-aged and lab-aged catalysts to gain a fundamental understanding of the differences between the catalysts. The team is currently developing techniques such as EPR to monitor in situ active site changes. The reviewer believed that all these techniques should allow for the eventual understanding of the poisoning of the active site on the field-aged catalysts. The reviewer was curious to know—and was not sure this is sufficiently addressed enough in the slides—how the team intends to model the lab-aged catalysts to "copy" the field-aged ones. What techniques will be used to simulate a similar poisoning mechanism?

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 results of finding new aging results—using hydrogen (H_2) temperature-programmed reduction (TPR) and other methods—helped with seeing new differences due to field aging.

Reviewer 2:

The reviewer remarked that technical accomplishments included identifying gaps between field-aged and existing simulated-aged catalyst behavior, developing a model catalyst synthesis and aging protocol, and using new tools and methods in studying field-aged catalysts.

Reviewer 3:

The project appeared to be running on schedule to the reviewer, and early results point toward a possible mechanism for the advanced aging.

Reviewer 4:

The reviewer believed some of the necessary steps were taken to understand the atomistic poisoning mechanism. The fundamental characterization of the active sites has occurred, but it would be better if there were more concrete evidence that Cu-sulfate formation occurs. The reviewer would like to have seen steps taken to bridge the gap and to synthesize model catalysts.

Reviewer 5:

The reviewer said hydrothermal and hydrothermally aged (HTA)/S aging protocols were used to compare with field aging. The team carried out extensive characterization of the Cu species and NH_3 storage in the aged catalysts and identified the gap between lab- and field-aged parts. Again, since the unknown poison could be the key missing piece to explain the discrepancy between lab- and field-aged parts, the reviewer asserted that elemental analysis of the field-aged parts seems to be urgently required. If confirmed, this poison component could be added to the lab-aging protocol to make it more representative of the field aging.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented this is a cooperative research and development agreement (CRADA) project with a leading HD engine and aftertreatment manufacturer Cummins. As such, 50% of the cost is contributed by Cummins and their involvement in the project is significant. Argonne National Laboratory (ANL) is a collaborator as are two universities (Purdue and Tsinghua).

Reviewer 2:

According to the reviewer, there is excellent collaboration with the CRADA partner and good leverage of the Environmental Molecular Sciences Laboratory (EMSL) analytical capabilities.

Reviewer 3:

It was clear to the reviewer that Cummins and PNNL are working together on this project, as Cummins is providing PNNL with the necessary catalysts. Cummins and PNNL seem to be coordinating their studies together.

Reviewer 4:

The reviewer commented collaboration occurs across multiple national laboratories, industry, and academia and appears to be well coordinated. The generation of aged samples at Cummins that are then characterized at PNNL appears vital to the project.

Reviewer 5:

Although it is hard to tell exactly who contributed what, this reviewer asserted that Cummins has proven to be an excellent partner over the years.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented appropriate future work is proposed to complete the third and fourth milestones. This future work includes investigations of PNNL model catalysts and initiating aging model development with Cummins.

Reviewer 2:

The reviewer noted that very reasonable goals have been set for future research.

Reviewer 3:

The future work plan appeared to be reasonable to the reviewer, but there is no evidence of decision points or risk mitigation strategies.

Reviewer 4:

The reviewer believed that the intention to synthesize model catalysts to simulate real-world aged catalysts is clear, but was unsure about the steps that will be taken to achieve that. Will atomistic modeling, such as density functional theory, also be involved? The reviewer inquired, furthermore, whether this project will have to evolve and expand to tackle the new durability requirements. If so, how will the team overcome this impending barrier?

Reviewer 5:

It seemed to the reviewer that the critical information needed is whether or not there is additional poison in the field-aged parts and, if so, what the poison is. Therefore, it is unclear how the proposed work on the model catalysts could contribute to that. The reviewer said this concern also applies to the aging model development with the additional poison contributing to the catalyst deactivation mechanism. If confirmed, this poison could be added to the accelerated lab-aging protocol to better represent field aging.

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

Reviewer 1:

The reviewer affirmed that, yes, this project supports DOE objectives as it addresses a key aspect of the United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) Partnership's ACEC tech team's roadmap—aftertreatment technologies for clean diesel combustion. It also improves domestic fuel efficiency in the transportation sector and contributes to environmental protection.

Reviewer 2:

The reviewer stated this project directly addresses barriers in understanding the fundamentals of aging SCR catalysts and therefore supports the DOE objectives.

Reviewer 3:

SCR catalyst performance after aging is critical to achieving very high NO_x efficiencies in the field for diesel vehicles, according to the reviewer.

Reviewer 4:

The reviewer asserted that this project supports the overall objectives of the DOE by helping an industry partner to develop better aftertreatment options, which in turn may allow for increased fuel efficiency.

Reviewer 5:

This reviewer explained that improved emissions control allows original equipment manufacturers (OEMs) to optimize energy efficiency of the entire engine and aftertreatment system.

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 these laboratories have excellent resources for carrying out their tasks.

Reviewer 2:

The reviewer observed that $300,000 per year of DOE investment in a 50% cost-share CRADA with a major industry partner seems appropriate for this important project.

Reviewer 3:

Financial resources for this project appeared to be adequate to the reviewer. The team itself is very strong.

Reviewer 4:

The reviewer said the team indicated sufficient funding was already provided to complete this project.

Reviewer 5:

According to the reviewer, resources are sufficient for this project.

Presentation Number: ace032
Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): Nitrogen Oxide Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems
Principal Investigator: William Partridge (ORNL)

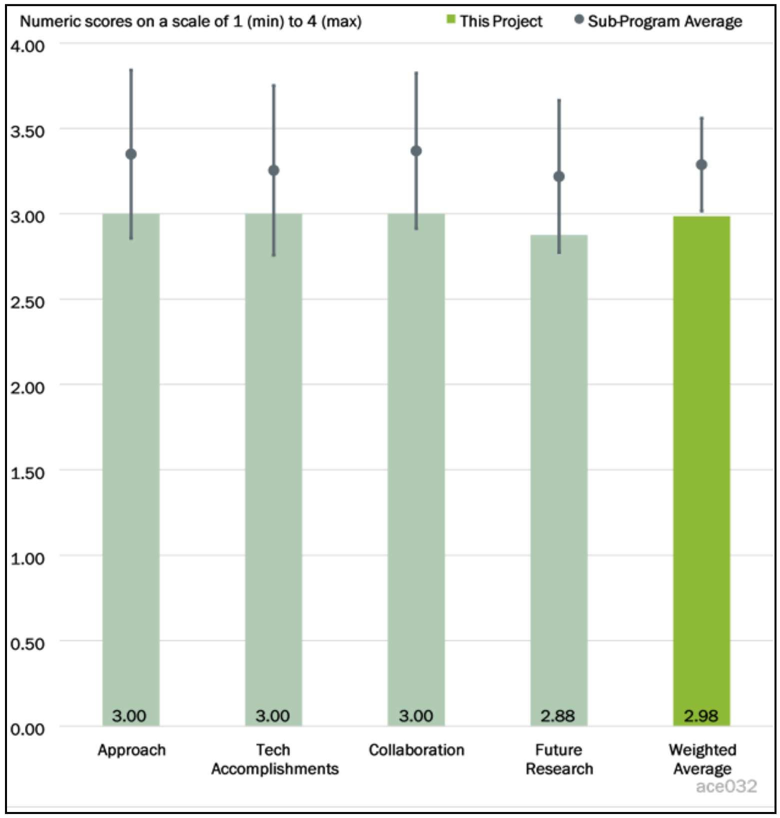

Figure 1-5 - Presentation Number: ace032 Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): Nitrogen Oxide Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems Principal Investigator: William Partridge (ORNL)

Presenter

William Partridge, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 project seeks to address barriers to SCR aftertreatment for diesel engine NO_x control including emissions control cost, SCR effectiveness under low-temperature applications, and robustness and durability in real-world applications. The project focuses on the challenge of understanding the impact of field-aging on catalyst durability under real-world driving conditions.

According to the reviewer, key components of the approach are determining the kinetic impacts of field aging by analyzing transient reduction and oxidation half cycles (OHC) to quantify the impact of aging on each half cycle and validating a Cummins SCR kinetic model using the experimental results.

The project approach is well designed and has been adapted to address barriers, prior reviewer comments, and the different characteristics of a new commercial Cu-SSZ-13 SCR catalyst.

Reviewer 2:

The reviewer remarked that the recent work has focused on obtaining the kinetic parameters for a rather detailed model that is being developed in collaboration with the industry partner, Cummins. It is good to see the new reactor is running, as this should accelerate the work and model development. It was a little surprising to the reviewer that there was a switch in catalyst "late" in the project, which hopefully was not a delayed switch from a formulation dropped in 2015. This catalyst switch may be not so critical as the chemistry should be primarily the same, except for the aging aspects. The reviewer said, overall, it is apparent the results are beneficial in understanding how the SCR catalyst works and will be extrapolatable to aging.

Reviewer 3:

The work has generally been executed with sound technical approaches. However, there appeared to the reviewer to be some limitations associated with the correlation between the aged samples and the functional mechanistic behaviors. The catalysts used for the work performed were field-aged parts, which provide the most realistic aging behavior. However, the reviewer noted that this catalyst choice results in significant unknowns that limit the technical success of the work. For example, the aging conditions seem to be completely unknown to the researchers, and the individual aging parameters (S, hydrothermal, inorganic metals, etc.) are unknown and not decoupled. The reviewer asserted that these aging conditions will limit the technical success of this work.

Reviewer 4:

The reviewer stated the work includes examining SCR catalysts (one newer one) in field testing, matching their performance versus an OHC/reduction half cycle (OHC/RHC) kinetic model, also matching it against the CLEERS model. From that perspective, the work is satisfactory, though not exemplary. Further, the cornerstone of the project is to focus on low-temperature SCR performance; however, it was unclear to the reviewer why most of the analysis focused on the temperature range 200–400˚C, barely considered low temperature. It would have been more relevant had it mainly focused on 150–250˚C, a far more challenging "low-temperature" consideration.

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 an improved transient response reactor was developed, enabling unattended programmed operation to improve efficiency and reduce time needed to complete experiments. Although previous reviewer comments raised concerns that too much effort had been devoted to reactor improvements, the investigators maintain that the improved reactor was necessary to effectively evaluate the new Cu-SSZ-13 SCR catalyst and that the improved reactor has enhanced the project.

The reviewer observed that experimental work characterized the effect of field aging on limiting the redox half cycle and demonstrated that field aging selectively degrades the OHC at a higher rate, shifting the optimum temperature to higher values.

The Cummins kinetic model was shown to capture important features of catalyst behavior with temperature, including the fast initial transients, bimodal nature of the transient response, and the faster overall transient response with increasing temperature.

Reviewer 2:

Again, bringing the new reactor online should accelerate results becoming available, as will the inclusion of a new researcher, of course. The reviewer indicated that the recognition of a need and development of a new protocol for characterizing the aged catalysts should also lend confidence in the results. And, of course, the results supporting the model development internal to Cummins as well as being used to validate the open source CLEERS models are important.

Reviewer 3:

The reviewer commented progress is generally proceeding according to schedule and milestones.

Reviewer 4:

The reviewer said while there is progress relative to last year, only investigating "one" newer SCR catalyst (Cu-SSZ-13) does not signify substantial progress. The entire project is about field-aged catalysts; however, the presenter did not know "how field-aged" the catalysts were. Lightly aged? Moderately aged? Strongly aged? The reviewer further highlighted that a histogram was unavailable to show mileage and temperature distribution.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found good collaboration with Cummins to provide field-aged samples for the experimental evaluation and kinetic modeling of catalysts. Johnson Matthey provided model catalyst samples. The addition of Johnson Matthey as a CRADA participant is a positive development that will strengthen the CRADA work.

Reviewer 2:

Judging from the presentation, the collaboration among the team members appeared to be fine to the reviewer.

Reviewer 3:

It was apparent to the reviewer that Cummins is using the data obtained to tune and develop the project team's kinetic models. The sample switch is concerning and not necessarily from the fact that sometimes formulations change, but more from why the switch occurred. The reviewer commented that this answer would have helped justify.

Reviewer 4:

The reviewer said collaboration generally appears to be meeting expectations. However, there were some examples where it appeared that communication between the partners was limiting project success.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future research topics were relatively limited in scope, according to the reviewer. This work focused on significant catalyst performance characterization and detailed microscale changes.

Reviewer 2:

The reviewer stated that there appears to be a long list of future work to be done (Slide 29). That said, again, while there are some good topics included, judging from that list, a focus on low-temperature performance appears missing.

Reviewer 3:

The proposed work appeared ambitious to the reviewer, given past rates. Yes, there is a reactor now online, but to characterize and confidently assign kinetic parameters for the de-greened, field-aged, and hydrothermally aged catalysts is a lot, given the technique and effort needed. The reviewer also said it appears the focus is about to switch to the ammonia slip catalyst (ASC), without closure on the SCR.

Reviewer 4:

The project is 86% completed in the final year. The reviewer was not clear on what work was planned to complete the current scope of work and what work was planned as part of a planned renewal.

The reviewer said a future renewal is planned to focus on adding an ASC to address NH_3 emissions and to determine the impact of field aging on the kinetics of commercial CU-SSZ-13 SCR catalysts.

The presentation identified several remaining challenges and opportunities for future work but did not present a detailed plan for specific work that will be proposed in a renewal application.

According to the reviewer, the project needs a more detailed plan for completing the work under the current project scope.

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

Reviewer 1:

The reviewer stated that the project supports DOE VTO objectives of improving diesel efficiency by enabling NO_x aftertreatment solutions for advanced low-temperature combustion (LTC) technologies for diesel engines through development of advanced SCR catalysts.

Reviewer 2:

The reviewer remarked that good SCR means good fuel economy, which coincides with DOE fuel economy goals and other targets.

Reviewer 3:

The reviewer stated HD diesel is not being eliminated via electrification. Therefore, emissions from these engine types need to be mitigated. With engines lasting longer, the aftertreatment system must also last longer, and the results from this effort will help achieve this.

Reviewer 4:

The project does an acceptable job supporting DOE objectives. However, the reviewer thought that the body of research is not as advanced as it could or should be for a DOE-funded project. There are many similar projects going on in the public and private domains, executing very similar (if not identical) work as part of application development programs.

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

Reviewer 1:

With a reactor online to take the data and personnel now available, the reviewer said that results will flow.

Reviewer 2:

Resources seemed to be sufficient to the reviewer for the planned work scope.

Reviewer 3:

The reviewer observed no resource issues.

Reviewer 4:

According to the reviewer, improved programmable transient reactor will increase efficiency of experimental work.

Presentation Number: ace033
Presentation Title: Emission Control for Lean Gasoline Engines
Principal Investigator: Vitaly Prikhodko (ORNL)

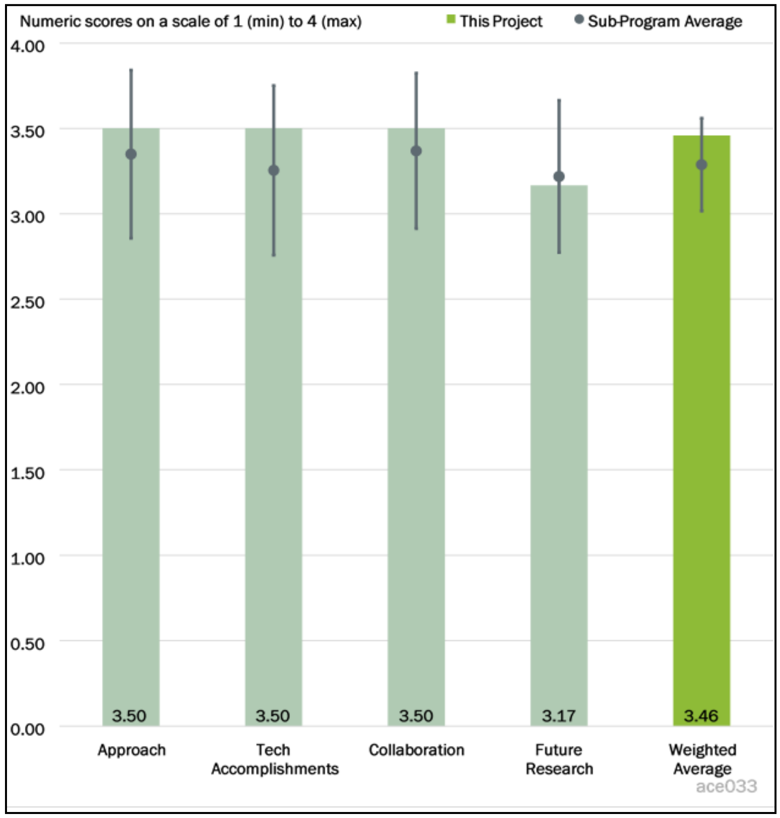

Figure 1-6 - Presentation Number: ace033 Presentation Title: Emission Control for Lean Gasoline Engines Principal Investigator: Vitaly Prikhodko (ORNL)

Presenter

Vitaly Prikhodko, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 the approach to study passive SCR strategy using a flow reactor and engine study is a great approach. Using the MAHLE jet ignition engine is another excellent approach.

Reviewer 2:

The reviewer stated the project continues to be a good blend of reactor testing and engine testing. The assessment of the SCR durability as a function of aging temperature and air/fuel (A/F) ratio (lean, stoichiometric, and rich) is particularly commendable. It will be interesting to see the early emission and fuel economy results on the new MAHLE engine, although the higher HC emissions and lower exhaust temperatures (from the Annual Merit Review [AMR] 2020 presentation) may present a challenge.

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 there is great work on the SCR durability research. The NH_3 temperature programmed desorption (TPD) and H_2 temperature programmed reduction (H_2 TPR) results were helpful for characterizing the catalysts after aging. It appears the SCR B2 formulation was a significant improvement over the earlier generation of SCR catalysts. The reviewer commended the project team for being able to install the new dynamometer and engine during a pandemic.

Reviewer 2:

The reviewer asserted that installing the MAHLE jet engine is significant progress in this research. In addition, improving the engine testing capability with the new AVL dynamometer is an important accomplishment. NH_3storage at high exhaust temperatures during stoichiometric operation appeared to be a concern to the reviewer. Air injection could potentially cool the exhaust by diluting it; however, oxidation of NH_3 could be an issue.

The reviewer suggested that some computational fluid dynamics (CFD) analysis for cooling the exhaust could help develop exhaust heat transfer technology to lower exhaust temperatures prior to the SCR and help in NH_3 storage.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found good collaborations with GM and Umicore.

Reviewer 2:

GM and Umicore participation in this work is vital, and the project team appeared to the reviewer to have a strong collaborative effort.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer noted that the clean-up-catalyst increased the NO_x emissions by oxidizing NH_3, and it also significantly increased the PGM content of the system (150 gallons per cubic foot [gpcf] Pt/Rh in the clean-up catalyst [CUC]). Adding air injection will only make the NH_3 oxidation worse and increase the system cost as well. The reviewer commented that other methods to reduce the carbon monoxide (CO) emissions need to be explored. If the exhaust O_2 could be reduced during the rich periods with better A/F mixing, then NH_3 could be generated over the three-way catalyst (TWC) while running less rich. The reviewer opined that better mixing will also result in less CO and possibly eliminate the need for additional aftertreatment just for the CO. If the engine had both a direct-injection (DI) injector and a port fuel injection (PFI) injector as found on some production engines, the PFI injector could be used during the rich periods to obtain better A/F mixing and thereby generate less O_2 and CO. The reviewer asserted that lower O_2 will allow the project to run less rich while still generating NH_3 over the TWC, and this rich reduction will further reduce CO emissions. The effects of S on the aftertreatment will need to be revisited with the new engine and catalyst system.

Reviewer 2:

Future research work appeared to the reviewer to target all important questions. Engine dynamometer testing will be the ultimate judge of the fuel reduction capabilities of a passive SCR approach.

The reviewer asked whether the project team will look at other technology additions, such as air injection, exhaust design, and a high thermal inertia TWC to improve NH_3 storage in SCR catalyst to improve the duration of lean operation.

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

Reviewer 1:

The reviewer stated lean burn engine use can reduce the fuel consumption of gasoline engines by up to 15%, which will help satisfy DOE's goal of reducing our dependence on foreign oil. This project is particularly relevant because it is developing aftertreatment for a lean burn engine that can satisfy Tier 3 Bin 3 emission standards after realistic aging while significantly increasing the fuel economy of the engine.

Reviewer 2:

The reviewer commented lowering fuel consumption from gasoline engines can be effectively achieved with lean-burn systems. However, urea as a consumable is not attractive for passenger cars; therefore, the success of a passive SCR system can be a game changer.

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

Reviewer 1:

Resources seemed to be sufficient to the reviewer for now.

Reviewer 2:

The new dynamometer and MAHLE engine are interesting resources to the reviewer to test the efficacy of this approach.

Presentation Number: ace056
Presentation Title: Platinum Group Metals (PGM) Reduction in Three-Way Catalysts (TWCs)
Principal Investigator: Yong Wang (PNNL)

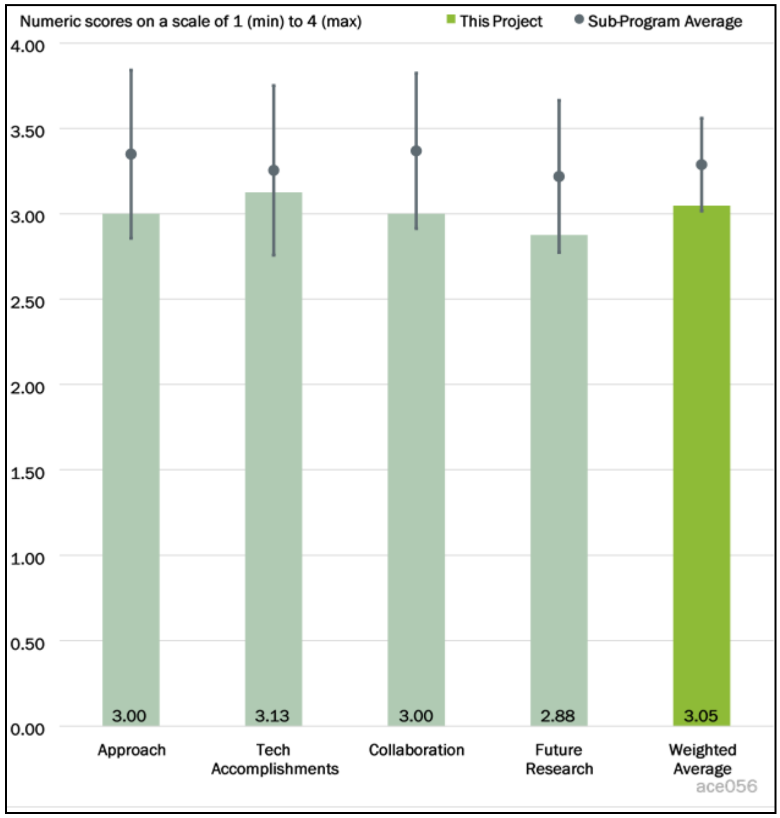

Figure 1-7 - Presentation Number: ace056 Presentation Title: Platinum Group Metals (PGM) Reduction in Three-Way Catalysts (TWCs) Principal Investigator: Yong Wang (PNNL)

Presenter

Yong Wang, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 research to be based on sound scientific principles to address technical challenges associated with the project.

Reviewer 2:

The reviewer stated the summary of last year's results included evaluation of reduced Rh contents through SAC, evaluating ruthenium (Ru) as a replacement for other PGM components and also evaluating Pd and Pt SAC. SAC, for a variety of chemistries, has grown in interest and focus over the last several years, so the team is able to leverage the knowledge being gained for synthesis and chemistry. The Rh results were interesting to the reviewer, who encouraged the team to include the rates for the higher than 0.1 loaded samples to support the conclusion that the 0.5 Rh is also a single atom throughout the experiment. Q&A suggested the rate versus loading flattened out, and such a finding would be critical for those working in this area. The findings with cerium-zirconium (CeZr) supports were also intriguing to the reviewer, who inquired as to why the performance shifted in temperature and how might the synthesis be tuned to mitigate the addition of the Zr effect? This is exciting work.

Of the work done, the reviewer's primary concern would be the inclusion of Ru in the study, rather than focusing on the single-atom aspects. Ru has known volatility issues, which are one of the focus points, but from a manufacturing aspect that volatility would or could be challenging. The reviewer opined that the industry partner should provide support and justification for the effort put toward studying Ru.

Reviewer 3:

The PI did a good job presenting the work, displaying the highlights and interim results. The presenter noted that this is a tough problem, and the goals point to conflicting targets such as reducing PGM while going down in activity temperature (150C). The reviewer said the team is doing a good job in addressing the challenges. Ru is indeed a potential alternative to Rh, but its fate remains uncertain, especially in the view of prior work.

Reviewer 4:

The reviewer stated the project is focused on developing effective TWCs for low exhaust temperature applications (less than 50°C) and reducing PGM content in catalyst formulations. The approach includes investigating the interface between single metal atoms and the support needed. According to the reviewer, the approach requires developing special characterization tools needed to support this effort.

The presentation could provide more detail about the research approach.

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 several, light-off, style tests were included, with computational and surface characterization studies from the partner supporting the view of what the surface looks like and what the surface is doing. The team has published two papers on the Rh work for NO mitigation. The reviewer said there is a third paper noted for natural gas, although this paper was also brought up in the response to last year's reviewers' comments as not an area of focus. The results regarding NH_3 are quite interesting to the reviewer. Overall, when reviewing the main material and the supporting slides, it is apparent that meaningful work is ongoing.

Reviewer 2:

According to the reviewer, technical progress achieved to date is equal to expectations for this project.

Reviewer 3:

The reviewer remarked that progress has been good, but further challenges remain (aging, poisoning, manufacturing, and cost considerations), as obvious from the presenter's statements.

Reviewer 4:

Although there is still a need to evaluate S tolerance of the catalysts, this reviewer observed commendable accomplishments date, which include the following:

- Synthesized thermally stable Rh atoms that are highly active for NO reduction by CO with full NO consumption achieved at 115°C.
- Demonstrated 0.1 weight percent (wt.%) RH1/CeO2 catalyst with full NO conversion at 125°C, which similar performance to 0.5 wt.% RH/CeO2.
- Demonstrated minimal effect of propylene addition.
- Demonstrated undegraded catalyst after hydrothermal aging at 900°C.
- Identified promising Pd and Ru/CeO2 catalysts.
- Made progress overcoming Ru volatility by trapping Ru as single atoms in 0.1 wt.% and 0.5 wt.% Ru.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that collaboration with the project team has been good, thus far, in the project.

Reviewer 2:

The reviewer said the interaction between PNNL and the University of Sophia was obvious. The integration of the computational aspects and experimental aspects was presented for the Ru case. The contribution from Stellantis was not made obvious.

Reviewer 3:

The roles of the collaborators appear to be well coordinated. The reviewer suggested that the project team provide more specifics about the work each partner is performing.

Reviewer 4:

The team has Stellantis and Sofia University onboard. In the reviewer's opinion, these team members are definitely not sufficient, however, given the tremendous challenges the project faces and will face. The presence of an entity strong in materials research and development (R&D) (beyond PNNL) or an OEM strong in catalyst research (i.e., Ford) is warranted. While PNNL is outstanding in fundamentals and leading-edge instrumentation, the reviewer did not believe that it has sufficient real-life (fieldwork-type) experience to decipher, when it is all done and good, what will remain a scientific experiment versus what will work as a practical catalyst in the end. Hence, a commercial material R&D entity could fill that gap, lowering the risk.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the proposed future work is entirely appropriate. The team is converging on the Rh single atoms and will dive further into understanding its chemistry, but also probing its stability. Rh is notorious for moving between atomic and particulate forms, so this should help the field understand its chemistry further. The reviewer suggested that other gases should also be explored during this phase.

Reviewer 2:

The reviewer stated the scope of this project is basic research. For the scope of basic research, the project has been very successful. The reviewer, however, wanted to see further planning and proposals for future applied research to ensure the increased likelihood of successful implementation of this technology.

Reviewer 3:

The reviewer commented the team has not sufficiently sifted through manufacturing potentials of likely catalysts; this was also brought up by another member of the audience and it could be a significant barrier, a potential showstopper. Likewise, more focus on aging (longer aging) and poisoning is warranted.

Reviewer 4:

Future plans to investigate hydrothermal stability, S tolerance, reasons behind TWC deactivation, and development of theoretical models to evaluate the NO conversion pathways are relevant to the scope or the project and DOE objectives. The reviewer needed information about decision points and the risks associated with the proposed future work.

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

Reviewer 1:

The reviewer stated the project is directly relevant to the DOE goals of reducing criteria pollutant emissions from ICEs.

Reviewer 2:

The reviewer indicated that the lower temperature catalytic activity can help save fuel (especially in the view of engine-out temperatures continuing to drop), consistent with the DOE goals of energy policy.

Reviewer 3:

The reviewer observed that PGM prices are extreme currently and reducing their content in aftertreatment catalysts while also improving the performance of such systems is critical for OEMs as well as minimizing emissions.

Reviewer 4:

The reviewer noted that the project addresses the DOE goal of improving fuel efficiency by enabling aftertreatment technologies that are effective at low exhaust temperatures typical of higher efficiency engines and the DOE goal of further reducing criteria pollutants.

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

Reviewer 1:

Resources appeared sufficient to the reviewer, with this conclusion based on what has been achieved and what is proposed.

Reviewer 2:

The reviewer stated resources seem sufficient to execute the proposed body of work.

Reviewer 3:

According to the reviewer, resources appear to be sufficient to accomplish the proposed scope of work.

Reviewer 4:

This reviewer referenced earlier comments and indicated that stronger aging considerations, more S emphasis, broader materials considerations, and integration of capabilities of a R&D-strong commercial entity are warranted.

Presentation Number: ace085
Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization
Principal Investigator: Todd Toops (ORNL)

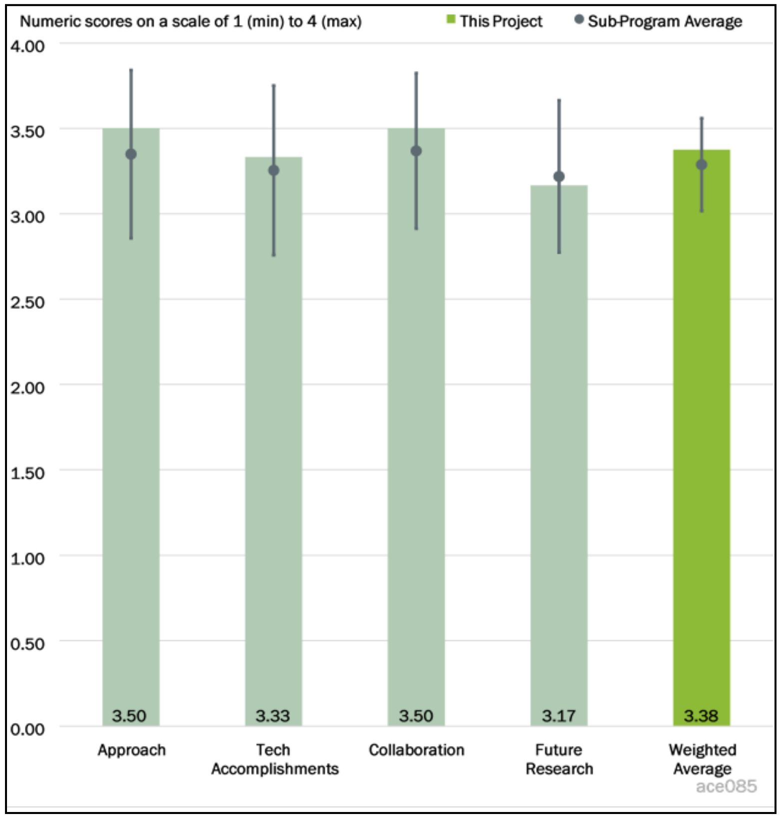

Figure 1-8 - Presentation Number: ace085 Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization Principal Investigator: Todd Toops (ORNL)

Presenter

Todd Toops, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 project team did a good job on using the ACEC testing protocols for the catalyst evaluations. The reviewer gave extra kudos for performing multiple NO_x adsorption tests on the PNAs and for investigating the addition of other materials (Cu, silver [Ag], and cobalt [Co]) in an effort to reduce the deactivation from CO. Also, the work on Pt catalysts is welcome, considering the high prices of Pd and Rh currently.

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 good work on investigating the effect of the Ce level with the Pt catalysts and showing that 60% Ce provided similar performance as the Rh-only reference catalyst. Nice work on showing the equivalent NO_x adsorption performance with the Pd/Cu combination with only half the Pd loading as the Pd-only sample. The reviewer stated the diesel oxidation catalyst (DOC), HCT, and PNA combination was interesting.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented good collaborations with the University at Buffalo, Harvard University, the University of Virginia, DOE Basic Energy Sciences (BES), and PNNL.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The PNA work needs to be expanded to other zeolites besides chabazite (CHA), BEA, and zeolite Socony Mobil 5 (ZSM-5) since these three zeolites always show some deactivation after tests with CO. The reviewer suggested considering lowering the total HC level to a level more consistent with diesel exhaust during a cold start, such as 1,000 parts per million (ppm), and encouraged investigating system approaches to minimize the deactivation from CO, such as a front DOC. In addition to the 600℃ ramps, the reviewer said that the project team might consider performing the temperature ramps to 400˚C or even 300˚C, as these are more realistic maximum temperatures for diesel engines. For the TWC work intended for stoichiometric applications, the reviewer encouraged the team to evaluate the more promising catalysts after aging at 900C and even 950C. The OSC of the catalysts still needs to be assessed, particularly with the Pt-only samples as Pt is known to be less effective for promoting OSC compared to Pd and Rh.

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

Reviewer 1:

Developing low-temperature catalysts is important for meeting stringent emission standards on future fuel-efficient engines that generate lower exhaust temperatures. Assessing catalysts with reduced Pd and Rh loadings (e.g., Pt-only and Pd with co-cations) is also important, given the current market price of Pd and Rh. The reviewer asserted that this assessment will enable automotive manufacturers to produce fuel-efficient engines, while cost-effectively meeting strict emission standards.

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

Reviewer 1:

Resources seemed sufficient to the reviewer for now, although additional testing resources could be needed to explore different PNA formulations with different zeolites and/or active metals. Extra testing and aging resources might be necessary to perform OSC tests and for aging TWCs at higher temperatures.

Presentation Number: ace100
Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2
Principal Investigator: Darek Villeneuve (Daimler Trucks North AmerIca)

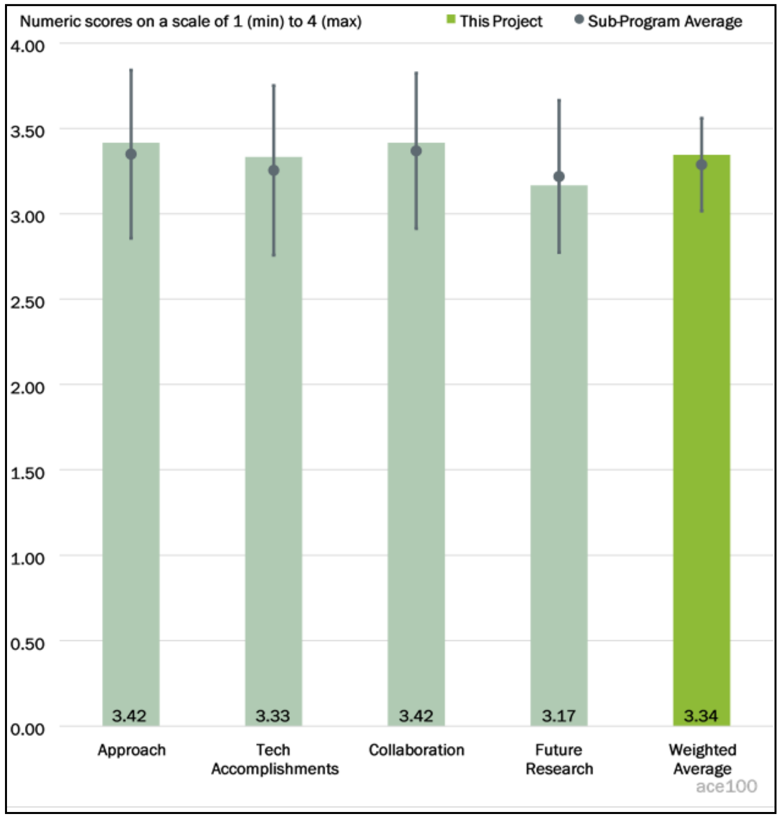

Figure 1-9 - Presentation Number: ace100 Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2 Principal Investigator: Darek Villeneuve (Daimler Trucks North AmerIca)

Presenter

Darek Villeneuve, Daimler Trucks North AmerIca

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 all technical barriers have been addressed adequately. The approach considers various aspects of engine and chassis level improvements.

Reviewer 2:

The reviewer found that the approach to the project is broad-based and appears to continue to focus on all aspects of the truck and trailer efficiency picture. Most of the discussed technical approaches are a stretch target beyond current off-the-shelf technologies, but not way out there. According to the reviewer, some technologies have been considered, which are pretty far out there (phase change cooling, for example). Including some of these advanced technologies, but not fully relying on them, has made the project more robust against challenges that come up during execution.

Reviewer 3:

The roadmap on Slide 4 clearly lays out the pathway to meeting the vehicle-level goals. The pathway to 55% brake thermal efficiency (BTE) on Slide 10 was a little more difficult for the reviewer to understand. It would have been helpful to the reviewer for the project team to identify the pieces of the bar chart (particularly for the combustion and air handling) regarding which technology each portion came from.

Reviewer 4:

The reviewer indicated that the project reported coronavirus disease 2019 (COVID-19) supply chain and workplace schedule impacts, which is an industry-wide challenge. This challenge included an 8-month delay in engine delivery; however, the project instituted recovery plans and is essentially on track for the original technical and project milestones, which reflects an effectively managed project. The reviewer commented that the team employed interim prototype hardware and analyses to validate the approach for the final demonstrator. This process has successfully identified risks and challenges in meeting targets, then taken steps to mitigate those.

Reviewer 5:

The reviewer stated the project is well planned and, given that it is near the end, the reviewer expects that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 6:

The approaches taken for both the engine and the vehicle are comprehensive, including all necessary puzzles to fulfill the vehicle project goal. However, the reviewer was not so sure if the project can achieve the engine goals of 55% BTE, partially because the technology roadmap depends on the progress of phase change cooling waste heat recovery (WHR). At this time, only simulated results are shown, and testing is on hold without any specific reasons.

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:

Given the challenges of project execution during the COVID-19 pandemic, the reviewer found that the progress on the project is excellent. The reviewer did not recall the exact timing of when the project started, but with the stated plan to complete the project during 2021, the accomplishments are quite good. The reviewer would like to have seen some preliminary numbers on where the powertrain efficiency was after the ORNL testing and ideally some indication of the freight efficiency level after the first prototype testing. The reviewer opined that it is a little hard to judge exactly how close the progress is relative to targets the way the efficiency stack-ups are shown with both tested and simulated results all included along the way.

Reviewer 2:

According to the reviewer, there are excellent accomplishments. The only gap is the WHR system, and it was not clear to the reviewer whether the 55% BTE can be achieved with the cyclopentane system. Slide 10 shows that the project is currently falling short of the goal. Also, it would have been good to see some results on criteria pollutants with the close-coupled (cc)-SCR used.

Reviewer 3:

The reviewer commented technical accomplishments were good, even though some delays were encountered due to COVID-19.

Reviewer 4:

The reviewer said the system design approach has seen some elements, such as tractor aerodynamics, not quite meeting original goals, but compensated for by better than planned improvements in other vehicle areas such as trailer aerodynamics. Much of the technical validation remains to be completed as the project team is waiting for vehicle completion and testing of the final demonstration vehicle in the final phase of the project. Prototype testing and analysis has provided confidence that the final demonstrator will exceed targets with some margin.

Reviewer 5:

In the past few years, the reviewer has been seeing a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Reviewer 6:

The reviewer stated significant progress has been made on the vehicle, including weight reduction, axles, tires, and energy management, which seems to indicate that the project should be able to achieve the vehicle goal.

The accomplishment on the engine seemed to be a little bit murky to the reviewer. Without phase change cooling WHR, it would be challenging to meet 55% BTE goal. Also murky is the current status of the engine BTE because the project team did not provide a clear current status report.

The reviewer asserted that another thing that needs clarification is what final version of the engine will be used for the final vehicle demonstration. The engine size due to twin turbo seems to be big, and the reviewer was not sure whether the engine targeted to 55% BTE can fit under the hood. Therefore, there is a disconnect between the engine and vehicle research.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said the project has effectively coordinated activities between participants during a challenging industry period dealing with COVID-19 supply chain and workplace issues. The team assembled is representative of appropriate expertise groups, including a tractor manufacturer, an engine manufacturer, a fleet, a trailer manufacturer, a tire company, two DOE national laboratories, and two universities. The team has effectively made use of available testing assets for virtual, bench, test cell, track, and road testing.

Reviewer 2:

The project looked like a well-coordinated effort to the reviewer.

Reviewer 3:

The reviewer said collaboration and coordination with all partners seem to be strong.

Reviewer 4:

The reviewer rated project as excellent because it does appear that several partners have been heavily used to achieve gains (trailer manufacturer, Michelin, and ORNL primarily). In a project as large as this one, it is clear there are many partners, but it is not clear how well things are coordinated at a detailed level.

Reviewer 5:

According to the reviewer, team members and their specific contributions were well laid out. It looks like a good team with industry, academia, and national laboratory members.

Reviewer 6:

The reviewer commented there seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. There should be more effort on fleet and other engagements in these projects.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated the demonstrator truck and demonstration of a 55% BTE engine are clearly identified in the future plans.

Reviewer 2:

The reviewer noted that the project is basically completed.

Reviewer 3:

According to the reviewer, the project is effectively planned and remaining work is tied to the availability of the final demonstrator. Interim steps were taken previously to reduce risk through the use of prototypes, virtual analysis, bench, test cell, track, and road testing.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a model year (MY) 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

Reviewer 4:

The reviewer said at this point the proposed future work is just to finish the outstanding tasks. It looks like the phase change WHR was dropped from the project. If so, the reviewer was disappointed as it would have been really interesting to see. However, it is also a challenging and high-risk technology so the reviewer could see why it might have to go as the end approaches.

Reviewer 5:

The reviewer remarked that it will be good to see results for NO_x emissions after all is done. Also, the status on WHR is not very clear, and it will be good to get a clear recommendation on whether the researchers find that phase change cooling has some significant barriers and should not be pursued in the future.

Reviewer 6:

The reviewer said the proposed future research should provide more details on how those technical barriers need to be overcome. Specific examples would include the potential issues of lacking phase cooling WHR, and the seem-to-be oversized engine. The reviewer said the project team will have an issue integrating the new engine into the final vehicle demonstration.

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

Reviewer 1:

The reviewer said the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up adopting zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

Reviewer 2:

The reviewer remarked that the project remains well aligned with the DOE objectives as of the time the project was started. Of course, the past 4 years have seen numerous changes in DOE objectives, so there is far less focus on decarbonization than would be desired right now. According to the reviewer, the project is still successful as it appears to address the DOE goals as set forth.

Reviewer 3:

The reviewer indicated that the project is clearly very relevant to improving fuel economy for transportation.

Reviewer 4:

The reviewer commented the project clearly contributes to the increased efficiency of freight transport and reduced energy consumption. The project meets DOE objectives.

Reviewer 5:

The reviewer stated the project supports the overall DOE objectives because of the significant improvement in the engine and vehicle performance and fuel economy.

Reviewer 6:

The reviewer found the project to be very relevant.

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 resources continue to look appropriate for the size of the project.

Reviewer 2:

The reviewer affirmed that, yes, the resources are sufficient for the project to achieve the milestones in a timely fashion.

Reviewer 3:

Looking back, the reviewer commented that maybe more resources could have been devoted to the aftertreatment system evaluation (understanding that it is not the main focus here).

Reviewer 4:

The reviewer stated that the team needed to overspend this past year, although it was not clear what the exact reasons were for this overspending. More details would be needed to determine whether an increase in funding would be appropriate.

Reviewer 5:

The project should have resources to complete the work, but t the reviewer was not sure if the project can achieve the engine 55% BTE goal with the current resources.

Reviewer 6:

The reviewer indicated that the project is 85% complete as of June 2021. Spending to date and the remaining budget were not clearly articulated; however, the project did not identify budget as an issue. The reviewer noted that much of the project rests on completing the build of the final demonstration vehicle, which may still be impacted by industry-wide COVID-19 supply chain related issues.

Presentation Number: ace101
Presentation Title: Volvo SuperTruck 2: 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 six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 17% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

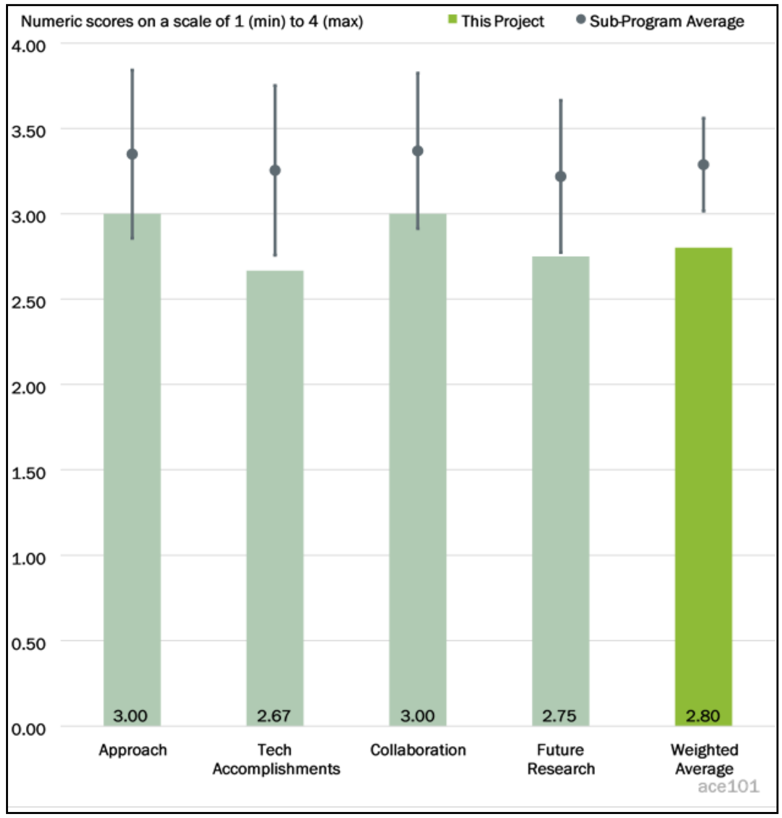

Figure 1-10 - Presentation Number: ace101 Presentation Title: Volvo SuperTruck 2: Pathway to Cost-Effective Commercialized Freight Efficiency Principal Investigator: Pascal Amar (Volvo Trucks North America)

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 proposed approach appears to be satisfactory to conduct the planned body of research. Investigators have done a good job managing simulation, bench testing, and engine test portions of work consistent with typical OEM product development.

Reviewer 2:

The reviewer stated all aspects of the project are covered by the approach.

Reviewer 3:

The approach is comprehensively described at a high level, but it was difficult for the reviewer to determine if the details are well designed for a project of this scale in a short presentation.

Reviewer 4:

The reviewer stated the project is well planned and expects it will be completed, given it is near the end. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 5:

According to the reviewer, the overall approach to the project has been executed well, dealing with impacts from COVID-19 supply chain and workplace related challenges. However, fundamental project configuration decisions have not been adequately explained. The fundamental assumption that a MY 2009 6×4 tractor capable of 80,000 pound (lb) gross vehicle weight rating (GVWR) can be replaced with a 4×2 tractor tuned to 65,000 lb GVWR remains questionable for fleets that carry a range of payloads on a daily basis. The project has not supported this decision in AMR review material. The reviewer indicated that this base assumption also has implications for residual value of the vehicle, which is a key factor in total cost of ownership (TCO) of fleet technology choices and a commercialization concern relevant to the project deliverables. Providing a comparison to a MY 2009 4x2 would make sense and/or comparison of a SuperTruck 2 6x4 configuration to a MY 2009 6x4. further confusion results from an inadequate discussion of 11 liter (L) versus 13 L engine aspects of the project. Since the project team stated the truck has designed for 6x2 and 6x4, at least some analysis of apples-to-apples comparison to the MY 2009 baseline 6x4 should be included in future review. These factors reflect on the project design and feasibility.

Reviewer 6:

Approaches taken for engine and vehicles have a few debatable flaws. The reviewer asserted that the 4x2 axle for a Class 8 vehicle is highly questionable for real-world applications due to the lack of traction and load distribution. The reviewer said that issues should be addressed. Regarding the engine, the reviewer wanted to know why two different engine platforms would be used for the vehicle and engine project separately. More specifically, a 13 L engine is being used for the engine development, targeting 55% BTE, while an 11 L engine is being used for vehicle development. Due to the engine size and displacement, whatever is being developed on the 13 L engine would not be directly applicable to the 11 L engine. The reviewer commented there is a strong disconnect between the engine and vehicle development.

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 technical progress and achievements to date are very impressive and show that the goals will likely be met. The “simulated - validation pending” items shown on Slide 10 (notably WHR) are a concern as these account for 5% BTE improvements, and it remains to be seen how much is actually achieved on the engine.

Regarding aftertreatment, it would be very valuable if a clear indication were given whether the electrically heated catalyst (EHC) is needed or not (for future regulations) and especially relevant to this project. The reviewer inquired about the fuel penalty.

Reviewer 2:

The reviewer stated the technical accomplishments look very good. Even with the explanation in the backup slides, it is still not clear on the Slide 10 bar charts what is accomplished going from the 11 L to the 13 L engine toward the 55% BTE goal. It would also be helpful if each bar of BTE gain were more explicit as to where those percentages came from in the list of technologies along the x-axis. The reviewer asserted that the 23:1 compression ratio (CR) seems really high for a turbocharged engine to stay under the peak cylinder pressure (PCP) limit of 250 bar, and it is likely absorbing much of the friction reduction from the liner friction reduction effort. Some additional explanation of this would be helpful.

Reviewer 3:

The reviewer commented the project presented again the project 55% BTE engine is a 13 L, but the demonstration vehicle is an 11 L engine. The presenter confirmed this is a slide responding to 2020 reviewer comments. While an efficiency waterfall chart was shown for the engine, none was shown for the entire vehicle, so reviewers were unable to assess state of contributions by system versus plan or actuals toward the 120% freight-ton efficiency (FTE) goal.

Reviewer 4:

In the past few years, the reviewer has been seeing a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Reviewer 5:

The current status of the engine BTE was still not clear to this reviewer. Although the roadmap presented in the progress slide—Validation of Powertrain Technologies—does provide a little sense of the progress, it did not give the reviewer any clear sense when combining the simulation with validated results in the same graphic.

A similar observation can be applied to vehicle progress as there are essentially no tangible achievements that can be assessed. For example, a 15% weight reduction in the trailer was mentioned. This 15% value lacks meaning if no baseline value is provided.

Reviewer 6:

Progress on this project is incredibly disappointing for a project so far along in its planned timeline. Actual demonstrated success (particularly on the powertrain) has been very limited, according to the reviewer. To date, the investigators have only demonstrated 48%-49% BTE on the engine. There are production engines for sale with higher BTE. Another 1%-2% improvement in BTE has only been demonstrated on bench tests, and the remaining 4%-5% BTE improvement exists simply in simulation at this time. The reviewer was not certain how the project will achieve the agreed upon milestones with the limited time remaining.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer indicated that the project seems like a well-coordinated effort across teams.

Reviewer 2:

A good team has been assembled and has well-defined roles. The presentation obviously does not have contributions from all the members. The reviewer assumed that some of project members have completed their work in prior years; that would explain why there was no mention of prior work in this report.

Reviewer 3:

The reviewer noted that the project has coordinated and collaborated while impacted by COVID-19 supply chain and workplace challenges. There have been delays, forcing some serial activities to become parallel ones. The reviewer said the project tapped outside parties to evaluate cruise control usage by industry drivers to help tune the technology use in the SuperTruck 2 demonstrator. The team assembled is representative of appropriate expertise groups, including a tractor manufacturer, an engine manufacturer, two fleets, a trailer manufacturer, a tire manufacturer, one DOE national laboratory, one major university, an industry group, and several major technology suppliers. The reviewer opined that the team has effectively made use of available testing assets for virtual, bench, test cell, track, and road testing.

Reviewer 4:

Collaboration across the development team seemed limited to the reviewer and is likely responsible for some of the developmental delays encountered.

Reviewer 5:

The reviewer commented there seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. There should be more effort on fleet and other engagements in these projects.

Reviewer 6:

It was not clear to the reviewer throughout the entire presentation how the individual team members help the project, although there is a slide to show the team members and their responsibilities. It would be clearer if each team member logo or something can be inserted into each of the progress slides.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the project is nearly done.

Reviewer 2:

The reviewer commented that the vehicle demonstration and engine BTE demonstration are scheduled to complete the project.

Reviewer 3:

The reviewer said there has been limited future research proposed to ensure continued development of efficient and clean internal combustion transport.

Reviewer 4:

The reviewer remarked that the proposed research is summarized in one bullet—perhaps indicative of the fact the project is in the last phase—but it would be good to see some more granularity on the next steps. It would also be good to include criteria pollutant measurements in the final demonstration.

Reviewer 5:

The reviewer said progress toward the 55% BTE engine appears on track for completion by the end of FY 2021, but the demonstration is not slated until the end of the project in parallel with the complete demonstrator vehicle, likely due to the 8-month slip in engine delivery to the project. This slip represents some risk that the engine in the demonstration vehicle does not meet engine tests cell performance project objectives, or that changes coming out of the engine testing will necessitate vehicle changes mid-stream in validation testing. The reviewer indicated that these risks may impact validation test schedules and/or budgets. Some contingency planning may be needed if road testing needs to be repeated due to unexpected configuration changes to the engine. The reviewer noted that an approved project slip into FY 2022 would permit a more sequential validation of the engine in the test cell, then validation of the completed vehicle with the engine. It would also permit validation of the 11 L engine in the test cell in addition to the 13 L engine because the demonstrator is slated for the 11 L engine.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a MY 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

Reviewer 6:

The reviewer stated the proposed future research is over-simplified with just a few sentences that do not address the technical issues faced to achieve the project goal, specifically on the engine side.

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

Reviewer 1:

According to the reviewer, the project clearly contributes to the increased energy efficiency of on-road freight movement and therefore meets the DOE objectives.

Reviewer 2:

The reviewer said the project focuses on improving transportation energy efficiency.

Reviewer 3:

The reviewer stated the project's objectives are clearly relevant to improving the fuel economy of the HD fleet.

Reviewer 4:

The reviewer commented that the project supports the overall DOE objectives.

Reviewer 5:

The reviewer noted that the project supports the overall DOE objectives of improved engine and vehicle performance and fuel economy.

Reviewer 6:

The reviewer said the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up adopting zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

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

Reviewer 1:

Resources looked sufficient to the reviewer.

Reviewer 2:

No funding issues were brought up in the presentation, so the reviewer assumed that funding is good, in spite of COVID-19.

Reviewer 3:

The reviewer affirmed that, yes, the resources are sufficient for the project to achieve the stated milestones.

Reviewer 4:

The reviewer stated the project reports 80% complete as of June 2021. Spending to date and the remaining budget were not clearly articulated; however, the project did not identify budget as an issue. The reviewer stated much of the project rests on completing the build of the final demonstration vehicle and parallel engine validation, which may still be impacted by industry-wide COVID-19 supply chain related issues or unforeseen technical challenges. The project team requested a schedule extension due to COVID-19-related schedule slips; this may have budget impacts on labor, where expedited fabrication and shipping or prioritization of facilities must be funded.

Reviewer 5:

Based on the success achieved to date relative to the funding level provided, the reviewer felt that the resources provided to the project team are too great for the results demonstrated.

Reviewer 6:

The reviewer wished that the rating included one more between sufficient and insufficient. It is not clear whether the project will have enough resources to achieve the engine BTE goal, given the way it was presented by the current form. The reviewer stated the contractor should be more transparent on the progress.

Presentation Number: ace102
Presentation Title: Cummins-Peterbilt SuperTruck 2
Principal Investigator: Jon Dickson (Cummins-Peterbilt)

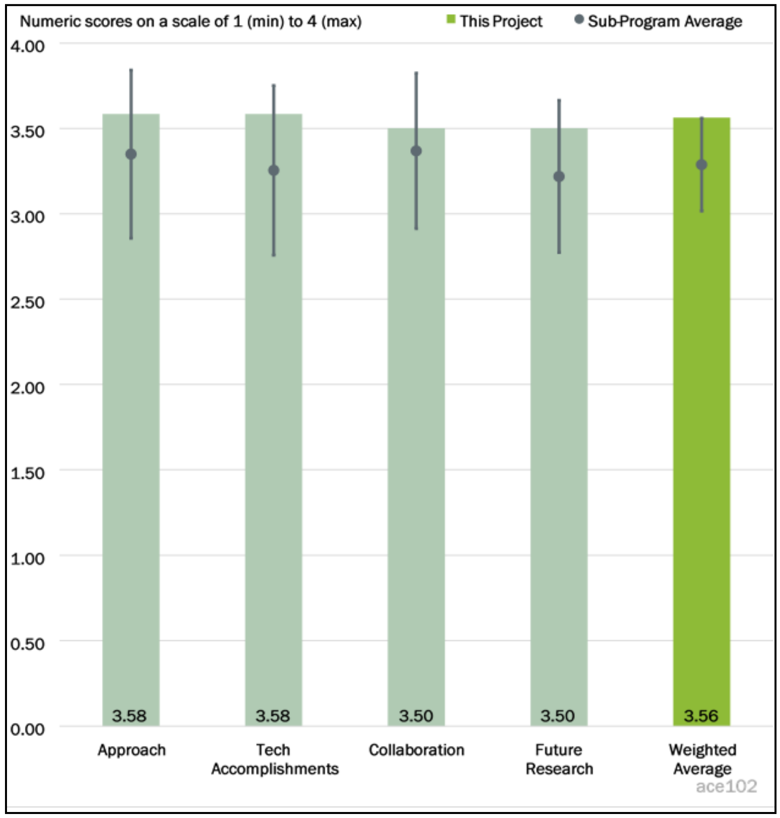

Figure 1-11 - Presentation Number: ace102 Presentation Title: Cummins-Peterbilt SuperTruck 2 Principal Investigator: Jon Dickson (Cummins-Peterbilt)

Presenter

Jon Dickson, Cummins-Peterbilt

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 Cummins achieved 55% BTE on its engine and addressed other project goals very well. Using a Walmart-simulated route is a great idea to demonstrate the improvements on a practical and important fleet.

Reviewer 2:

The reviewer stated Cummins/Peterbilt team has an excellent and thorough approach to the SuperTruck project goals and called the work well done.

Reviewer 3:

The reviewer said the project reports being on track toward validating the 55% BTE engine goal in early 2021 and on track to greatly exceed the original DOE 100% FTE target estimated now at exceeding 170%. The overall project management was the only team proactively stating to DOE that COVID-19 would impact project schedules at the AMR 2020 review and took steps to responsibly extend the project. The vehicle design shows significant innovation across a range of technologies, for example, using active aerodynamic systems such as the variable extender device for yaw conditions and the lightweight hybrid material chassis. The project has effectively employed analysis and early prototype mule and bucks to expedite validating project assumptions and integrating hardware and software systems. The reviewer said engaging the National Renewable Energy Laboratory (NREL) to obtain and analyze 56 Walmart routes with real vehicles and loads for use in designing the SuperTruck 2 demonstrator and choosing a representative test route spoke to the project's confidence level and project and team integration maturity.

Reviewer 4:

The reviewer opined that the project has been very well defined and, more importantly, very well executed. All technical approaches taken were very well justified and represent beyond SOA technologies.

Reviewer 5:

The reviewer commented that the project is well-planned and expects that it will be completed, given it is near the end. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

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 asserted that meeting 55% BTE on its most advanced engine platform is a great achievement. The project will also be on the way to overachieving the vehicle performance goal well beyond the minimum 125%.

Reviewer 2:

The reviewer thanked the project team for the nice summary of vehicle-level accomplishments on Slide 10 and Slide 21, as well as the additional information in the "Reviewer Only" slides. That additional information was very helpful to see the full depth of accomplishments the team made. The reviewer stated well done.

Reviewer 3:

The reviewer praised the great progress in achieving 55% BTE. The reliance on WHR for more than 4% improvement is a bit concerning, not for this project but overall. The reviewer inquired about what the economics of WHR are and whether the team is running out of levers if WHR is not used.

Unlike other teams, the reviewer noted that there seems very little emphasis on aftertreatment system, and while that is not the focus here, it would be good to understand the thoughts on how cc-SCR or other advanced components are expected to impact the solutions in this project.

Finally, the reviewer indicated that all eyes are on the final fleet demonstration.

Reviewer 4:

The reviewer remarked the project achieved a 55% BTE in early 2021. NREL's collecting and analyzing duty cycle data for 56 Walmart actual routes and loads is a significant accomplishment and deliverable on its own as this level of current granularity is needed for understanding freight system optimization. Hardware design for the entire vehicle is largely complete. The reviewer noted that tare weight reduction goals have been exceeded without compromising GVWR. Rolling resistance targets have been exceeded. Technology commercialization is demonstrated as impacting near-term product designs. The reviewer said key long lead components have been procured or are in process to support vehicle completion at the end of 2021.

Reviewer 5:

The reviewer stated that, in the past few years, a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments has been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency. The reviewer stated the project was weak on evidence.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that there was great collaboration.

Reviewer 2:

The reviewer stated the number of partners and suppliers involved in the vehicle looks quite extensive. This project has a strong team with excellent leadership.

Reviewer 3:

The reviewer remarked that the project has effectively coordinated activities between participants during a challenging industry period dealing with COVID-19 supply chain and workplace issues. The team assembled is representative of appropriate expertise groups, including a tractor manufacturer, an independent engine manufacturer, a fleet, a trailer manufacturer, a tire company, a DOE national laboratory, and multiple Tier 1 and Tier 2 suppliers. The reviewer said the project has effectively made use of available testing assets for virtual, bench, test cell, track, and road testing.

Reviewer 4:

The reviewer asserted that collaboration with all team members is amazing, which is one of the major reasons that the team has achieved the project goals so aggressively and early.

Reviewer 5:

The reviewer commented there seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. There should be more effort on fleet and other engagements in these projects.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented that the future research and remaining work are all very defined, which shows that the team is on the way to achieve all the project goals.

Reviewer 2:

The reviewer reported that it was very good to see the cost and payback model included in the future research.

Reviewer 3:

Completing the vehicle demonstration looked to be well on track to the reviewer.

Reviewer 4:

The reviewer stated the project is nearing completion.

Reviewer 5:

The reviewer said the project scope and deliverables in the remaining work are significantly beyond the original DOE targets. The total system effectiveness depends on final completion of the vehicle build in 2021, then adequate testing in 2022. The project steps to this end appeared organized and coordinated to the reviewer. Confidence with total vehicle integration is due to interim use of mule and bucks to identify and resolve issues prior to final design and build.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a MY 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

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

Reviewer 1:

According to the reviewer, project support is very relevant to reducing fuel consumption in the HD transportation sector.

Reviewer 2:

The reviewer stated improvement in vehicle efficiency to reduce the energy needed to move U.S. cargo over the road meets the DOE program objectives.

Reviewer 3:

The reviewer said the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up adopting zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

Reviewer 4:

The reviewer commented that the project absolutely supported overall DOE objectives by substantially improving the engine and vehicle performance and fuel saving.

Reviewer 5:

The reviewer stated the project supported the overall DOE objectives very well.

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

Reviewer 1:

Resources looked sufficient to the reviewer.

Reviewer 2:

All looked to the reviewer to be on track with the original budget.

Reviewer 3:

The reviewer affirmed that, yes, resources are sufficient for the project to achieve the stated milestones.

Reviewer 4:

The reviewer stated the project has all the resources needed to achieve the project goals.

Reviewer 5:

The reviewer remarked that this project stated in the AMR 2020 review that COVID-19 would impact the schedule significantly. The project maintained some level of progress on long lead supplier parts during this period, while project direct resources at Peterbilt were not charging to the project. The reviewer indicated that that seems to have preserved the project labor budget while keeping some progress on hardware going. Schedule impacts do not appear to have thus impacted the project budget, as the project reports it is 85% complete and spend to date is 94% of budget. The reviewer said the project is stretching into FY 2022, so there is some risk of labor overrun or hardware overrun if testing encounters any failures or issues.

Presentation Number: ace103
Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck
Principal Investigator: Russell Zukouski (Navistar)

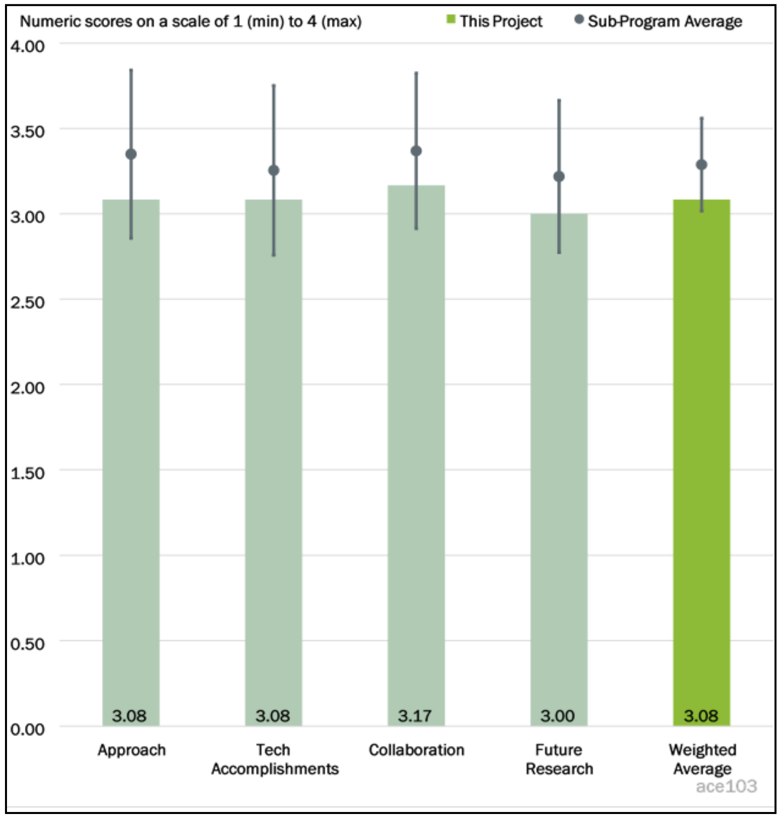

Figure 1-12 - Presentation Number: ace103 Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck Principal Investigator: Russell Zukouski (Navistar)

Presenter

Russell Zukouski, Navistar

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 approach examines all the key subsystems of the vehicle including engine, powertrain architecture, vehicle attributes of weight and aerodynamics, the trailer, and operations like cruise control. The reviewer noted innovative attempts to improve the engine with fuel injection, air management, and cylinder deactivation. There was a good effort on emission controls.

Reviewer 2:

The reviewer found a very good overall approach, touching on all aspects of the project and also considering the aftertreatment system (Slide 8) for low NO_x.

Reviewer 3:

The reviewer said the project is well planned and, given it is near the end, expects that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 4:

The reviewer remarked that the overall approach to the project demonstrated a systems' engineering approach by looking at multiple solutions, evaluating opportunities and challenges, then down-selecting to address maturity, cost, risk, and other competing factors. The use of composite materials instead of aluminum or steel has a mixed history with HD trucks due to cost and durability factors. The reviewer also said evaluating sourcing sustainable wood-based products and recycling ramifications of foam core-based products should be discussed in the next review as potential challenges to commercialization and TCO of these weight-saving concepts.

Reviewer 5:

The reviewer stated that the roadmap for the vehicle seems to have all the important technologies to achieve the vehicle performance goal.

It is programmatically correct to drop the gasoline compression ignition (GCI) engine project, which should have happened earlier, since this part of the project had no chance to meet the project goal. The reviewer, however, was not convinced that the approach taken has all the technology pieces to achieve the engine project goal at 55% BTE. The resources taken on cylinder deactivation and aftertreatment improvement on cold start do not have anything to do with 55% BTE, which is a single point at high loads.

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:

According to the reviewer, the Navistar team made excellent progress in tractor and trailer lightweighting, the hybrid system seems on target, and there is innovation and progress in the ladder frame. The engine and WHR improvement are still in progress, but the effort is probably better focused by ending the GCI investigation. The reviewer said it will be interesting to see the impacts of cylinder deactivation.

Reviewer 2:

The reviewer found very good progress so far. It will be good to see the WHR improvements with the final specifications being achieved on the engine, given that it contributes more than 3 BTE points. It would be good to understand the cost-benefit considerations of WHR since all teams seem to need this capability, but also it is the one technology that has not yet been fully demonstrated and seems challenging.

The reviewer asserted that emphasis on the aftertreatment system is very good, as is the evaluation of more than one configuration including EHC. The reviewer asked the project team to please analyze the fuel penalty of EHC in future work.

Reviewer 3:

The reviewer said the technical accomplishments of the project are tied to completing the demonstrator vehicle and adequate validation testing. To date, the hardware, software, and design appear to be on track to supporting this goal. The reviewer commented that the system approach to the design added a hybrid system, which impacted vehicle weight, but was compensated for by improved energy efficiency.

Reviewer 4:

In the past few years, the reviewer has been seeing a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Reviewer 5:

Lack of tangible improvements on the engine and vehicle make it hard for the reviewers to assess the project progress. It seems to point out that the engine may have trouble meeting the 55% BTE goal. It seemed to the reviewer that the project has cancelled one of the major project developments on gasoline engines during this year compared to last year, or no progress has been made. The project should report the status of this progress regardless.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The total team is very large (for the better), providing inputs in technology, testing, and analysis. The reviewer noted that the team, including suppliers and various contributors, is actually larger than the list shown on the summary slide.

Reviewer 2:

The reviewer emphatically stated that the project is well-collaborated.

Reviewer 3:

It seemed to the reviewer that each key team member plays a role in helping to develop this project.

Reviewer 4:

The reviewer stated there seems to be little evidence to the claims made concerning industry engagement outside the specific partners that are funded. There should be more effort on fleet and other engagements in these projects.

Reviewer 5:

The reviewer said the project assembled an expert team of collaborators, including university, fleet, national laboratory, tractor manufacturer, trailer manufacturer, engine supplier, and multiple Tier 1 and Tier 2 suppliers. The team effectively made use of virtual analysis, bench, test cell, and track and road testing in gaining confidence for the final demonstrator design. A concern for the reviewer was the level of participation of real-world fleet information. The project seems to be relying extensively on established internal duty-cycle information from historical projects. As the market has significantly been evolving in recent years with e-commerce, growth in third-party logistics companies (3PLs), reaction to supply chain shortages, etc., the reviewer opined that this project provides the OEM with an opportunity to validate market assumptions and duty cycles rather than just making use of existing historical 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated the project is nearing completion.

Reviewer 2:

The reviewer said there are indeed some remaining challenges and targets to be met. These challenges were clearly described and reviewed in the presentation.

Reviewer 3:

The reviewer asserted that the future work has not been spelled out separately, although some indications are given on individual slides. It will be good to understand with more clarity what remains to be done and by when. The reviewer stated it will be good to include the impact of advanced aftertreatment systems on the fuel penalty.

Reviewer 4:

In spite of delays due to COVID-19 supply chain and workplace challenges, the reviewer remarked that the path to completion appears to be on track. Some technical elements are still being fine-tuned. The reviewer said the inclusion of ultra-low NO_X objectives is proactive for future commercialization viability. Future planning was not presented in sufficient detail to evaluate the remaining project milestones in Budget Period (BP) 5.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a MY 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

Reviewer 5:

The reviewer stated the proposed future research seems to be too vague, which does not provide the enough details to address the technical challenging to achieve the project goals, specifically for the engine.

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

Reviewer 1:

The reviewer stated this project is very relevant to reducing fuel consumption from the transportation sector.

Reviewer 2:

The reviewer said the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up adopting zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

Reviewer 3:

The reviewer said this project supports the overall DOE objectives to improve engine and vehicle performance and fuel economy.

Reviewer 4:

The reviewer stated project supports the overall DOE objectives very well.

Reviewer 5:

The reviewer observed that the project directly supports reducing fuel petroleum use, reduced carbon emissions, and reduced criteria pollutants—these accomplishments are all part of DOEs mission. The freight sector continues to grow in its fuel use and carbon emissions due to more freight movement and vehicle-miles traveled (VMT). The reviewer said the projects for higher efficiency and low emissions should continue with high priority. Projects would be even stronger if they include paths to using low-carbon fuels.

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

Reviewer 1:

Resources looked sufficient and well used to the reviewer.

Reviewer 2:

The reviewer affirmed that, yes, resources are sufficient for the project to achieve the stated milestones.

Reviewer 3:

The reviewer said the SuperTruck 2 program has not enjoyed funding as large as SuperTruck 1; so, this project is on the low end of sufficient. Cost share by industry is a key enabler.

Reviewer 4:

The reviewer wished that the rating included one more rating between sufficient and insufficient. It appears the project should have enough resources to achieve the vehicle goal, but the reviewer was not certain if it has all it needs to achieve the engine goal of 55% BTE.

Reviewer 5:

The reviewer said the project reported 80% project complete as of June 2021. The project did not report spend-to-date against plan. The project did not identify budget as a significant challenge. The reviewer said the project is estimating completion by the end of 2021. Conflicting information was presented on the state of the demonstrator build, which in one schedule slide was ticked as more advanced (complete) than in the subsequent detailed slides and Q&A discussion with reviewers. The reviewer said this discrepancy may indicate some level of risk with maturity of designs or hardware availability with respect to the stated schedule completion. Extending the schedule has budget ramifications on labor and/or facility use.

Presentation Number: ace118
Presentation Title: Advanced Nitrogen Oxide Storage
Principal Investigator: Janos Szanyi (Pacific Northwest National Laboratory)

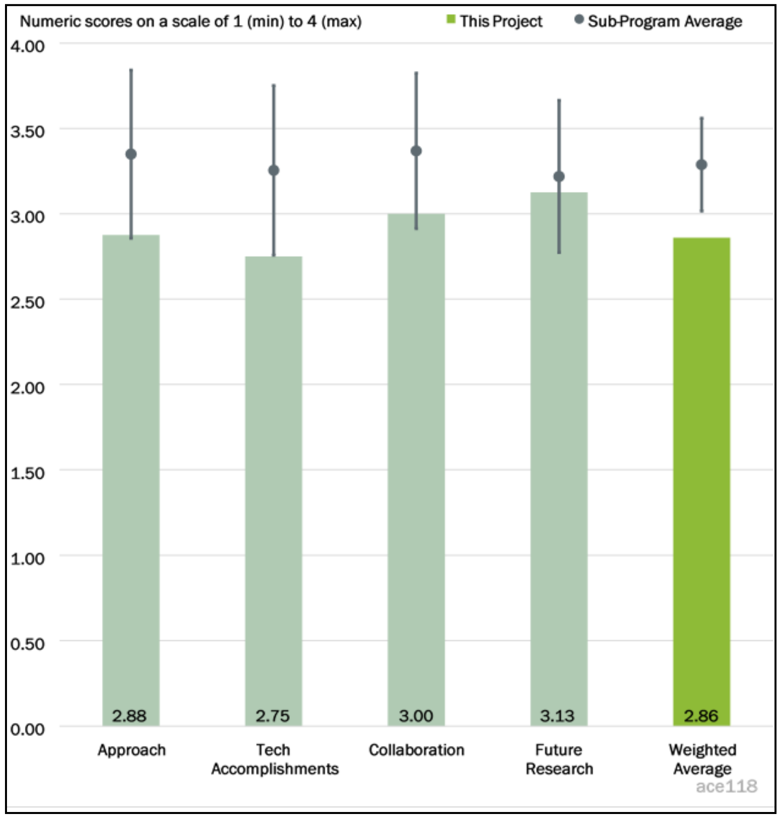

Figure 1-13 - Presentation Number: ace118 Presentation Title: Advanced Nitrogen Oxide Storage Principal Investigator: Janos Szanyi (Pacific Northwest National Laboratory)

Presenter

Janos Szanyi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 there is a good approach to leveraging core PNNL expertise in fundamental sciences (chemistry and catalytic materials) coupled with close collaboration with ORNL and industry BASF.

Reviewer 2:

According to the reviewer, the project makes good use of PNNL's strong characterization capabilities. It is good to see a non-Pd based approach being explored with the rubidium (Rb) work.

Reviewer 3:

With the stated application being a TWC for stoichiometric gasoline vehicles, the reviewer opined that the NO_x storage catalysts need to be aged and evaluated under simulated gasoline exhaust conditions (see the low-temperature aftertreatment [LTAT] protocol published by CLEERS). So far, only results relevant to diesel applications (lean aging and testing conditions) have been presented. The reviewer also stated that a well-known deactivation mechanism for PNA (Pd/zeolite) is exposure to rich feed (CO, etc.), and it should be examined if the PI intends to study the PNA deactivation mechanism.

Reviewer 4:

The reviewer saw that a previous reviewer said this project "seems like a report on making a few varieties of PNA… but it is not focused on understanding." The reviewer generally agreed with this statement. While the technical aspect of the project is very strong, it appears to be an assortment of different projects tackling different problems without tying together any fundamental understanding to come up with just one PNA. Again, the fundamental work is very good, but the reviewer struggled to see a clear approach forward. Considering the rising costs of Pd and the slides on Ru/CeO_2, the reviewer wanted to know if the work is moving away from Pd and toward Ru. For the Ru work, the reviewer was worried about its stability, despite the 10 cycles of stability shown in one slide. In one of the slides using Pd, the project team mentioned going to 30 cycles; the reviewer, was interested in seeing more cycles performed after higher temperature aging. The reviewer did not believe that aging to 750°C is sufficient and asked what happens when these are aged to temperatures of around 900°C. The reviewer would also like to have seen how these PNAs react to poisoning, as well as more fundamental, experimental, and in-situ understanding of the adsorption mechanism on the Ru/CeO_2.

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 good technical progress was made on improving hydrothermal stability and performance, as well as understanding active sites.

Reviewer 2:

Everything appeared to the to be proceeding on schedule. The increased resistance to hydrothermal aging and exploration of non-Pd materials is encouraging.

Reviewer 3:

The reviewer said NO_x storage results obtained after diesel (hydrothermal) aging and evaluated under lean conditions may not be relevant for their performance under stoichiometric exhaust conditions. Hence, it was not clear to the reviewer whether the evaluated NO_x storage catalysts could be useful for the stated gasoline applications. No result was presented for these catalysts under stoichiometric test conditions.

Reviewer 4:

The reviewer indicated that part of the issue is that the goals appear to be changing. Will a key milestone remain the understanding of the mechanism on Pd/ferrierite (FER)? If so, the reviewer saw degradation of the PNA after 30 cycles, but did not necessarily see a mechanistic understanding of how or why. If the goals shift to an understanding of Ru/CeO_2, then the reviewer thought that there is more significant progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said collaborators include ORNL (sample exchange for performance verification), Sofia University (DTF calculations), BASF (industry input), and Carus (input on reactive NO_x storage).

Reviewer 2:

According to the reviewer, collaborators span a good cross section of national laboratories, industry, and academia. The most evident collaborative effort appears to be with the computational team at Sofia University. The reviewer said most of the work is concentrated at PNNL.

Reviewer 3:

The reviewer stated leveraging ORNL and BASF expertise is helpful as both have extensive experience with gasoline TWC catalysts. They can also provide assistance on relevant catalyst aging and test conditions.

Reviewer 4:

While the reviewer could understand the collaboration between PNNL and ORNL, the reviewer did not understand how there is collaboration with BASF. The reviewer wanted to know what BASF provides besides samples and input on industrial feasibility?

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future work appeared reasonable and well planned to the reviewer, but there is no indication that decision points or any risk mitigation strategies have been implemented.

Reviewer 2:

The reviewer stated it is good the team plans to evaluate the Ru catalyst under stoichiometric conditions, and it is critical that a proper aging protocol is also used to address gasoline applications. The last bullet point in the Proposed Future Work "Understand the potential interference and interactions with DOC etc." was not clear to the reviewer, who asserted that the team should be clear about the targeted application (gasoline or diesel) and use the proper conditions to generate relevant results.

Reviewer 3:

The reviewer commented that four future work activities as presented are appropriate for completing the remaining two milestones in FY 2021. This work was presented as a core R&D project for PNNL, but only for a single fiscal year. It was unclear to the reviewer if the work was funded under a DOE VTO lab call (typically a 3-year effort), if the scope is determined on a year-to-year basis, or if it is part of another PNNL project. More clarity on what shapes this work for future years would be helpful.

Reviewer 4:

The reviewer believed that pivoting to focus on Ru/CeO_2 is an excellent idea but remained skeptical about the stability of the Ru atoms after aging at 900+°C. The reviewer agreed with the need to understand all fundamental mechanisms, as well as the need to study the effect of different poisons.

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

Reviewer 1:

The reviewer affirmed that, yes, the work on passive NO_x adsorption is one possible pathway to address the 150˚CC challenge.

Reviewer 2:

The reviewer remarked that achieving greater than 90% conversion of criteria pollutants at 150℃ is required to achieving the U.S. Environmental Protection Agency (EPA) Tier 3 Bin 30 emission standard. This temperature requirement in turn allows increasing the efficiency of ICEs, which decreases dependence on foreign oil and reduces carbon emissions.

Reviewer 3:

The reviewer was not sure about the targeted application. Even though a TWC for gasoline applications was stated in the milestone, all the data presented so far are related to diesel applications.

Reviewer 4:

While the project does address the 150°C challenge that was posed years ago, the reviewer feared that the industrial need for PNAs has waned. With the rising costs of Pd; the lack of understanding of the multiple activation, deactivation, and degeneration-regeneration mechanisms; and the heavy influence of poisons on PNAs, the reviewer was concerned that the near future of PNAs in the automotive industry is in jeopardy unless there a radical new innovation in the field.

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

Reviewer 1:

The reviewer said the project is part of ongoing core R&D under CLEERS at PNNL funded at $400,000 per year.

Reviewer 2:

The reviewer stated the resources are sufficient for the project to achieve the stated milestones.

Reviewer 3:

Funding appeared to be adequate to the reviewer for this undertaking. The team and facilities are also well= suited to the work.

Reviewer 4:

The reviewer believed that the fundamental work performed in this project has been very impressive. However, due to the lack of prevalence of PNAs in the industry, the reviewer feared that the work is slowly becoming irrelevant.

Presentation Number: ace119
Presentation Title: Advanced Multi-Functional Diesel Particulate Filters (Deer and Company)
Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

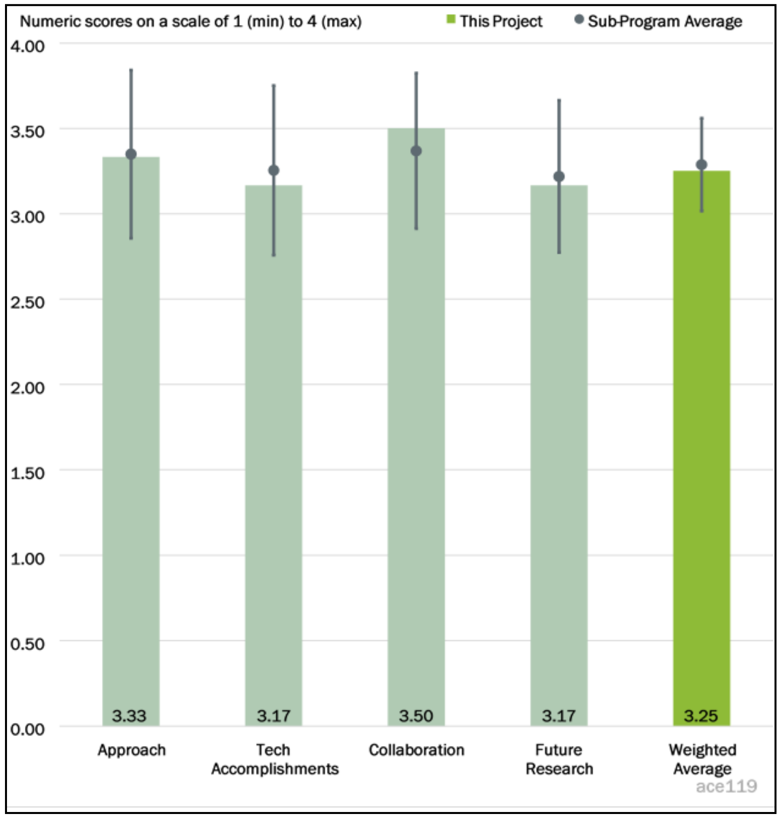

Figure 1-14 - Presentation Number: ace119 Presentation Title: Advanced Multi-Functional Diesel Particulate Filters (Deer and Company) Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Presenter

Ken Rappe, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 this to be appropriately near-term focused work for a 1-year CRADA project on a highly promising strategy of aftertreatment integration for cost reduction. It was a well-thought-out approach, starting with a literature review, followed by field-aged and accelerated testing to obtain characterization data for a DOC on a DPF (DOCF) to support model development.

Reviewer 2:

The reviewer stated the integrated DOCF concept has several potential benefits (compact volume, lower cost, etc.); however, it may also present some unique challenges. The catalyst washcoat and ash distribution in the device are clearly information factors, and they are adequately addressed in the project approach. The reviewer stated it will be helpful to also evaluate the effect of soot on the oxidation activities for both hydrocarbon and NO_x.

Reviewer 3:

The overall approach is good, though it was somewhat difficult for the reviewer to see the end application. Is the goal simply to develop and validate a DOCF model? The reviewer said it would be helpful to see some comparison to other systems, such as DOC + DPF + SCR or DOC + selective catalytic reduction on filter (SCRF) in order to assess the benefit of moving to DOCF.

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 good progress has been made in this relatively short project. The first milestone has been met (characterization of ash distribution in DOCF), and the second one is 60% complete (spatially resolved capillary inlet mass spectroscopy [SpaciMS] for DOCF), with some delay due to COVID-19 pandemic (laboratory access and vendor availability).

Reviewer 2:

The reviewer stated there is good progress overall. The performance results are limited to modeling so far, and it will be beneficial to show the experimental data (if available) for model comparison. In particular, HC-NO light-off test results (with and without soot) are useful information to assess the efficiency of this integrated concept for filter regeneration and SCR deNO_x performance.

Reviewer 3:

Overall progress appeared to be on track to the reviewer. The delays due to COVID-19 are understandable, but unfortunate.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the project is a good example of a short-term (1-year) industry CRADA that involves John Deere and Kymanetics.

Reviewer 2:

The reviewer stated there is good team collaboration with complementary capabilities.

Reviewer 3:

Collaboration partners are strong, but it was somewhat difficult for the reviewer to assess their levels of effort. Are there regularly scheduled meetings and/or discussions?

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said the project was a single-year CRADA that is 95% complete. Future research is appropriately focused on near-term completion of remaining tasking (X-ray computerized tomography [CT] data, parameterization study, and SpaciMS assembly).

Reviewer 2:

The reviewer referred to earlier comments along with saying that there is a good plan to have experimental data to validate the developed model.

Reviewer 3:

The proposed future work appeared reasonable to the reviewer, though there is no evidence using decision points or risk mitigation strategies. The reviewer wanted to know how the impact of aging is going to be studied and whether the impact of aging will add significant experimental scope to the project?

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

Reviewer 1:

The reviewer said the project supports the overall DOE objectives as it provides data and models to better understand the potential of DOCF as a promising strategy of aftertreatment integration that can reduce cost and space requirements on vehicles, reduce PGM use, and improve system responsiveness.

Reviewer 2:

According to the reviewer, the work supports the overall DOE goals through potential reduction in the cost and size of diesel aftertreatment systems.

Reviewer 3:

The reviewer commented that the project supports the overall DOE objectives of reducing emissions and improving fuel efficiency. The reviewer asked if this concept is uniquely suited to HD applications or if the device could also be applicable to light-duty (LD) vehicles too.

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 $200,000 of DOE funding with an 50% industry cost share was well spent on a 1-year CRADA project that investigated DOCF.

Reviewer 2:

The reviewer stated the resources were sufficient as indicated by the project team.

Reviewer 3:

Financial resources appeared to be adequate to the reviewer, and the team is well suited to do the work.

Presentation Number: ace124
Presentation Title: SuperTruck 2 - PACCAR
Principal Investigator: Maarten Meijer (PACCAR)

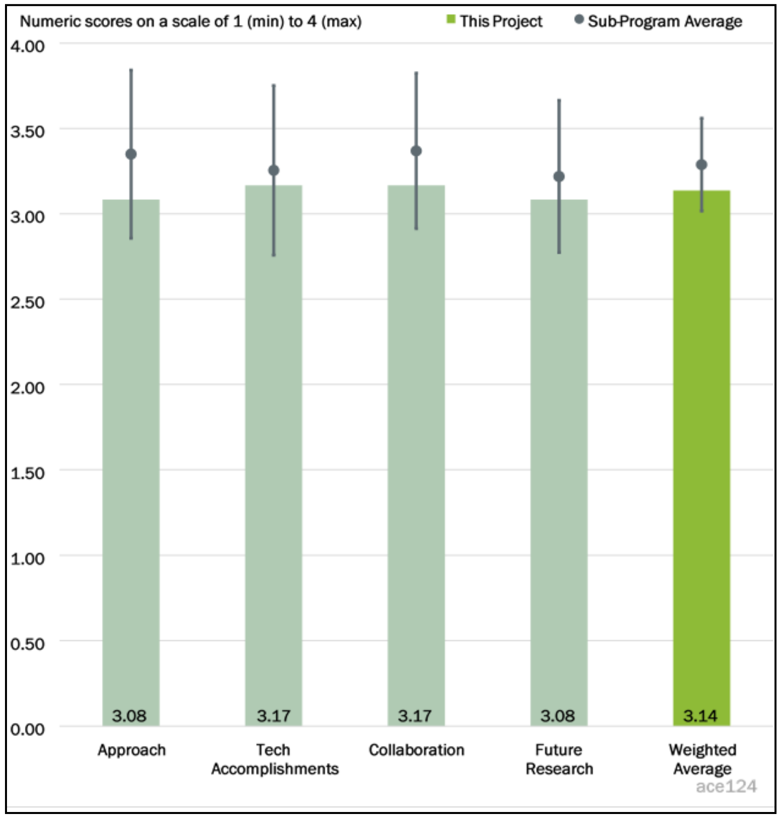

Figure 1-15 - Presentation Number: ace124 Presentation Title: SuperTruck 2 - PACCAR Principal Investigator: Maarten Meijer (PACCAR)

Presenter

Maarten Meijer, PACCAR

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 indicated that the approach to freight efficiency goals is very comprehensive across the engine, powertrain, and vehicle. It was a good use of electrification and some innovation in WHR and an impressive reduction in aerodynamic drag and weight. It will be interesting to see engine efficiency numbers through the long stroke.

Reviewer 2:

The reviewer said the project team reports that it is 75% complete as of June 2021; the project started 1 year later than the other SuperTruck 2 project teams. The project team is in the process of requesting a project extension due to COVID-19 challenges and stated that BP 3 extended 9 months. According to the reviewer, the team has an excellent systems approach to achieving project goals, with contributions from many systems, including an all-new non-conventional cab. The project has a path-to-target that greatly exceeds the original DOE objectives for the vehicle FTE improvement, now forecasted at 175% improvement. The reviewer found that the project team has effectively used team assets, such as virtual simulation, hardware-in-the-loop (HIL), test cells, track and engineering prototype mule to validate assumptions, and decisions for the demonstrator vehicle design, which reduced project risk. The team appears to have chosen a 4x2 configuration, which may limit its TCO, residual value, viability, and utility in the secondary market versus the baseline MY 2009 6x4 vehicle configuration.

Reviewer 3:

The reviewer stated the project is well planned and given it is near the end, expects that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 4:

Slide 7 indicated that 10% of the efficiency gain to reach 55% BTE was from friction reduction, but the reviewer did not see any mention of that variable in the presentation. If this was work done in previous AMR presentations, some supporting material in the backup slides for "reviewer only" would have been helpful as a refresher.

The reviewer said tackling the ultra-low NO_x in the project's engine demo and vehicle demo, are quite aggressive. The pathway to reach that goal was not detailed in the presentation, so the reviewer was hoping to see good things with that challenge next year.

Reviewer 5:

It seemed to the reviewer that the approach has most of the important elements to reach the projects goals; however, it is too early to tell or almost impossible to tell whether the approach taken can help the project achieve the engine project goal at 55% BTE, since there are no intermediate testing results to deduce the possibility. The project lacks a roadmap to see how the engine can achieve 55% BTE goal. It was hard for the reviewer to imagine that the engine can achieve the project goal at 55% BTE with one iteration of the new engine hardware, which sounds to be too optimistic, but not realistic. The vehicle has a fairly aggressive goal in achieving 175% improvement, but again, lack of a roadmap is a concern for how these technology building blocks can help the project to achieve this 175% 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 said good progress in spite of the COVID-19 situation. The description of the engine path needed more quantification of technology impacts. The reviewer noted good progress on electrification and chassis construction.

Reviewer 2:

The reviewer stated good technical progress is being made, but obviously at a slower rate with the 9-month COVID-19 related delay in BP 3. It will be interesting to see if the exploration of GCI for high efficiency and low NO_x works out, and it is good to see a SuperTruck 2 team explore some unique solutions.

It was not clear to the reviewer how much the team was going to rely on the exhaust aftertreatment (EAT) system to reach the ultra-low NO_x target. More information on that would be helpful.

Reviewer 3:

The reviewer asserted that the project has matured designs through analysis and prototype testing to achieve significant improvements. The project team reports tractor tare weight at 13,000 lb and trailer tare at 12,000 lb, representing significant reduction in tare weight while including all the new technologies. The reviewer said, however, the proposed demonstration vehicles appear to be a 4x2 configuration where the baseline MY 2009 would be a 6x4. The project team has not discussed at the AMR review the ramifications of tuning the vehicle to a 65,000 lb GVWR platform versus a baseline rated at 80,000 lb GVWR. The reviewer noted that aerodynamic improvement via CFD analysis shows a significant 60% improvement versus the MY 2009 baseline. Powertrain improvement has not yet been demonstrated for a 55% BTE but appears on track. Electrification of some accessory load is included in the design establishing a 48-volt (V) mild-hybrid system, including e-heating, ventilation, and air conditioning (HVAC) and e-steering.

Reviewer 4:

In the past few years, the reviewer has been seeing a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Reviewer 5:

The reviewer reported that noticeable progress was made on the vehicle. Aerodynamic improvement seems to be coming along, with a total drag reduction of 60%. The reviewer said powertrain efficiency and weight reduction also provide the improved values. It would be helpful if absolute values can be provided to better assess progress of the project.

The reviewer said, however, there are no intermediate testing results on an integrated engine in terms of BTE, making it virtually impossible to assess whether the team is able to achieve the engine project goal of 55% BTE with one iteration of hardware development.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that PACCAR has assembled an impressive, large team. The roles and contributions are clearly presented.

Reviewer 2:

The reviewer stated the project has a good, diverse team, taking advantage of key industrial partners as well as universities and national laboratories.

Reviewer 3:

The reviewer commented there seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. The reviewer believed that there should be more effort on fleet and other engagements in these projects.

Reviewer 4:

The reviewer stated it would be helpful to show how each of the team members plays a specific role in helping the project succeed by inserting their names or logo on each technical progress slide.

Reviewer 5:

According to the reviewer, the project has assembled a qualified team of expertise, including a tractor manufacturer, a DOE national laboratory, two engine manufacturers, an engine technology company, two universities, and major Tier 1 and Tier 2 suppliers. The engagement of Cummins for WHR puts competing engine manufacturers on the same team, which should benefit the technology maturity for the demonstrator. The reviewer said fleet involvement was not itemized in the presentation material, either in the introductory partner slide or the later partnerships and collaboration slide. The presenters verbally discussed customer involvement in design development, but this exchange was not detailed in the presentation. The reviewer suggested that the next review should include details of fleet engagement.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

There are good plans to move from the mule vehicle demo to the final vehicle demo and to the engine high BTE demo next year. The reviewer emphatically stated that it will be interesting to see if the computational prediction of 175% freight efficiency improvement can be demonstrated.

Reviewer 2:

According to the reviewer, the project did an acceptable job planning its future work.

Reviewer 3:

The reviewer said there is much to be done to reach the project goals. The needed future work is clearly shown. The reviewer commented that the prime path for the engine is diesel based. If GCI research will continue, the team might consider showing carbon reduction (CO_2 per ton-mile) with a gasoline-like, low-carbon fuel in addition to BTE achieved.

Reviewer 4:

The reviewer indicated that the proposed research should provide a more detailed roadmap, specifically for the engine, to show what barriers need to be overcome to achieve the project goal. Again, at this level, there is no idea of whether this project can achieve the engine BTE goal, since there is no baseline established and no intermediate results demonstrated. This sounds like a high-risk project to the reviewer.

Reviewer 5:

The reviewer said the project is three-quarters complete per the presenter, and with an approved extension it may be complete as late as FY 2023. While the technical, hardware, and software appear to be on track to achieving targets, the completion level at 75% with perhaps an estimated 2 years remaining of scheduled work indicate a five to six-year project. A final demonstration vehicle planned validation test program was not discussed in any detail in the AMR 2021 review.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a MY 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

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

Reviewer 1:

The reviewer commented that R&D toward reduced energy consumption and emissions in the freight sector is in line with DOE objectives and national needs.

Reviewer 2:

According to the reviewer, increased efficiency in freight movement of goods in the United States is in line with DOE objectives.

Reviewer 3:

The reviewer said the project supported the overall DOE objectives very well.

Reviewer 4:

The reviewer remarked that the project supported the overall DOE objectives by improving vehicle freight efficiency and engine BTE.

Reviewer 5:

The reviewer found that the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up the adoption of zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

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 the project has been designed to fit a budget of reasonable size, with large industry cost-share.

Reviewer 2:

The reviewer asserted that the project team gave no indication that the 9-month COVID-19 delay impacted the cost of the project, so funds are assumed sufficient.

Reviewer 3:

The reviewer affirmed that, yes, the resources are sufficient for the project to achieve the stated milestones.

Reviewer 4:

The reviewer said the project should have adequate resources to achieve the vehicle goal, but was not certain for the engine, since no reference and no baseline can be assessed.

Reviewer 5:

The reviewer asserted that the project team did not present spend-to-date versus plan nor detail the impact to the budget of the requested project extension. The project did not identify budget as a major challenge or issue. According to the reviewer, insufficient detail was provided at the AMR 2021 to accurately assess adequacy of resources. The project extension may require additional funding for labor or to obtain prioritization of vehicle validation resources.

Presentation Number: ace128
Presentation Title: Reduced Precious Metal Catalysts for Methane and Nitrogen Oxide Emission Control of Natural Gas Vehicles
Principal Investigator: Michael Harold (University of Houston)

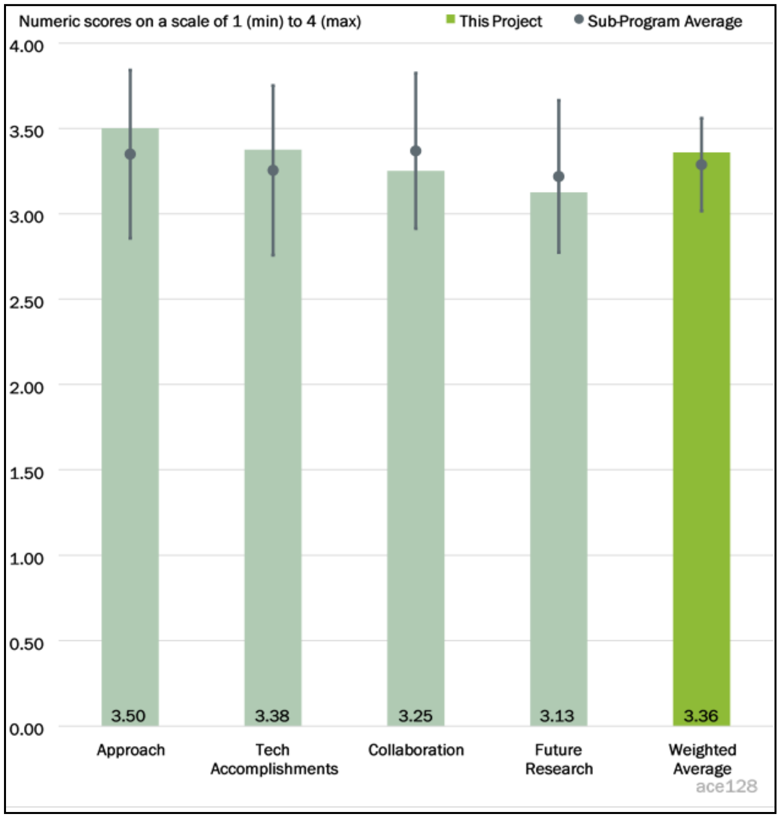

Figure 1-16 - Presentation Number: ace128 Presentation Title: Reduced Precious Metal Catalysts for Methane and Nitrogen Oxide Emission Control of Natural Gas Vehicles Principal Investigator: Michael Harold (University of Houston)

Presenter

Michael Harold, University of Houston

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 approach to performing work is based on sound technical principles and includes a combination of experimental and simulation capabilities, according to the reviewer.

Reviewer 2:

The reviewer said the project seeks to develop a four-way catalyst that reduces methane emissions from natural gas engines in addition to NO_x, CO, and non-methane hydrocarbons (NMHCs) by combining a spinel catalyst layer below a PGM catalyst layer.

The approach was logical to the reviewer as it proceeds from synthesis and screening of catalyst formulation, mechanistic and kinematic modeling, flow reactor testing, reactor model development and validation, feed modulation, S effects evaluation, identification of best materials, and prototype testing on a natural gas engine.

Reviewer 3:

The reviewer opined that the approach includes a good mix of material selection, experimental stages, and kinetic considerations.

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 the technical accomplishments and progress toward project goals to be excellent. Investigators are making sound progress with the experimental tasks and are able to effectively describe the experimental observations using simulation.

Reviewer 2:

According to the reviewer, the work appears to shed light on fundamentals of spinel impact along with H_2 formation and impact on methane (CH_4) oxidation. The accomplishments include insights on materials, kinetics, and modeling.

Reviewer 3:

The reviewer inquired whether this review is for BP 2 or BP 3? The slides show a BP 3 milestone, but the summary slide states that all BP 2 milestones have been achieved. A progress summary slide showing the project timeline and progress on meeting each milestone would help in evaluating project progress against budget period milestones and performance indicators. The reviewer found the organization of the presentation confusing as it pertains to the progress compared to milestones.

Progress includes an evaluation of $NiCo_2O_4$ spinel with results showing that adding CeO_2/ZrO_2 increases durability, spinel mitigates PGM S poisoning under certain conditions, and there is evidence of Fe migration to the PGM layer at high temperature. It appeared to the reviewer that the addition of more spinels is planned. The reviewer said that an addition of spinel results in a large transient spike in CH_4 conversion at the transition from lean to rich conditions. The spinel layer enhances conversion through removal or inhibitors CO and H_2 through oxidation by the spinel. The reviewer also remarked that the monolith reactor model development was progressing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Excellent collaboration is evident in the progress being made with all aspects of the project, according to the reviewer.

Reviewer 2:

The reviewer noted that the chart (Slide 5) describes the broad team involved. However, the presentation almost entirely focused on the work at University of Houston (UH) (and to some extent the University of Virginia [UVA]).

Reviewer 3:

The reviewer opined that this presentation better addresses the role each collaborator plays in the project, but does not provide many specifics of each team member's activities. Some additional detail could be provided in future presentations.

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

Reviewer 1:

The proposed future research is good, but to enable successful future product implementation, the reviewer would like to have seen more planning, proposed applied research, and a strawman for uncertainties around future product development.

Reviewer 2:

The reviewer said the project lead, Professor Harold, is clear on what needs to be done next—a deeper dive into characterization, lower light-off temperature, spatial changes during modulation, model development, etc., as indicated on Slide 21.

Reviewer 3:

It was not clear to the reviewer from the presentation as to where the work stands on meeting the project milestones and what work needs to be done to complete the milestones of the existing scope of work. The proposed future work is to converge on a next-generation catalyst, integration, modeling, and optimization. The reviewer stated this statement is somewhat vague. More detail is needed on the plan going forward. Where does the project stand in terms of completing the eight steps listed in the approach on Slide 5? What is the plan to complete that work going forward? Has the project met the BP 3 milestones?

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

Reviewer 1:

According to the reviewer, the project goal supports DOE objectives to reduce criteria pollutant emissions.

Reviewer 2:

The reviewer asserted that efficient CH_4 oxidation is energy resource management, a DOE charter.

Reviewer 3:

The reviewer found that the project is relevant to the goal of reducing emissions of CH_4 as a GHG from natural gas engines.

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

Reviewer 1:

The reviewer said resources appear to be sufficient for the work scope proposed.

Reviewer 2:

The reviewer stated the UH team and the ORNL team appear to have the instruments and resources needed to keep the project on track.

Reviewer 3:

The reviewer reported that resources seem to be sufficient to meet the project objectives and scope of work.

Presentation Number: ace133
Presentation Title: Next-Generation Heavy-Duty Powertrains
Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

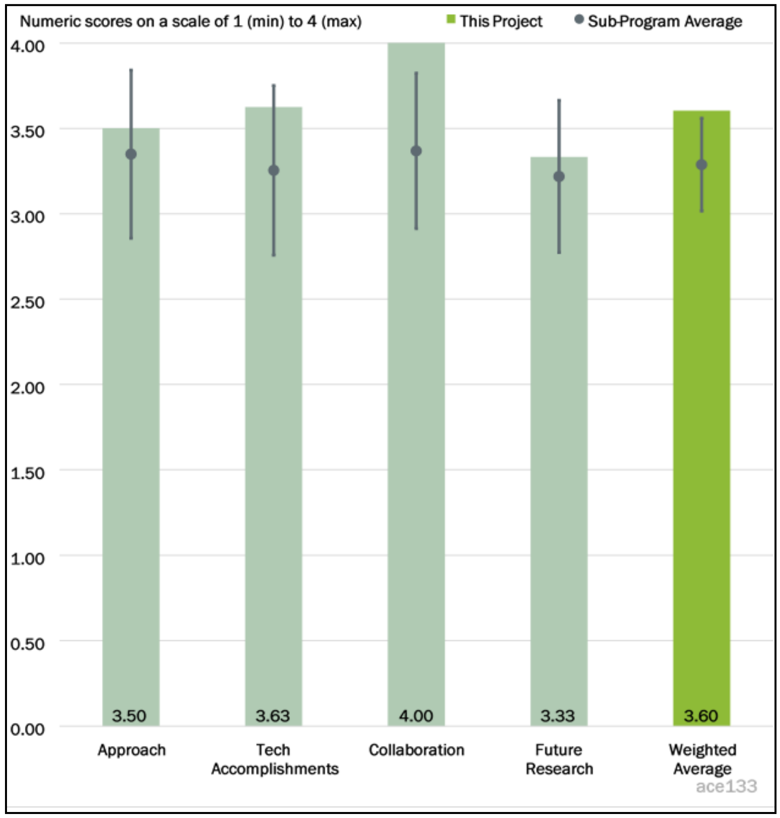

Figure 1-17 - Presentation Number: ace133 Presentation Title: Next-Generation Heavy-Duty Powertrains Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

Presenter

Scott Curran, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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:

Critical barriers and the approach for performing the work are well defined, according to the reviewer, who enthusiastically praised the work.

Reviewer 2:

The reviewer stated the project is a complex and diverse set of four tasks. The project team has done an excellent job of combining task areas where relevant (diagnostics from Task 1 in Task 2 and common engines in Tasks 3 and 4). There is clear line of sight for the project to be feasible and achieve the goals of each task or at least make significant research progress on each task.

Reviewer 3:

The reviewer remarked that this project covers a large body of diverse work and is well executed, though the reviewer was not sure how it is all related. Given the very specialized facility required for neutron imaging, the reviewer questioned if this is the best method to rely on or if other methods can be used to diagnose injector issues, etc. GCI seems to have the emissions problems of diesel with less efficiency. What is the “why buy” for GCI? The reviewer commented that a comparison to diesel would be helpful. Stop-start emissions are a relevant problem, and the reviewer looked forward to seeing that work.

Reviewer 4:

The entire project seemed to the reviewer to have an integrated approach to each of the tasks supporting the overall goal. Task 1, if successful, should provide valuable temperature information in-cylinder. This information should be helpful to validate simulations, particularly in conjugate heat transfer (CHT). Task 2, especially the running engine at the Spallation Neutron Source (SNS), should provide valuable information about the materials in-cylinder during actual engine operation. The reviewer said Task 3 appears to be exploring some useful areas in GCI, although the investigation into different injection strategies is likely reaching a useful asymptote. There is essentially zero pathway toward commercialization for partial fuel stratification (PFS) and, at this stage, the scientific understanding is well-enough developed that additional PFS work has a very limited rate of return. The reviewer opined that it would be helpful to see other advanced engine technologies and their influence on a GCI engine, such as cylinder de-activation (CDA). The goal might be better served to study strategies that produce a maximum of 2.0 gram per horsepower-hour (g/hp-hr), and focus attention on documenting exhaust temperature and improving efficiency using different parameter sweeps around that NO_x output. Task 4 should be quite useful for MD applications, with limited usefulness for HD applications.

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:

Good progress has been made on this project with a majority of the milestones being met, and the reviewer asserted that the team is on track to complete the remaining tasks in time to meet the remaining milestones.

Reviewer 2:

The reviewer found that the technical progress demonstrated to this point has been impressive. There has been a large amount of work done and the results are very encouraging.

Reviewer 3:

The reviewer noted that Task 1 progress is excellent to outstanding, given the diagnostic development, initial demonstration, and 95% accuracy validation. The Generation 2 probe indicates significant knowledge from Generation 1 and seems to be moving to a very useful tool directly used by industry. The reviewer asked for comments on the bounds of use for this tool regarding different engine combustion environments that are more optically thick. The current application looks to be limited to low cylinder density flame propagation engines and not mixing-controlled compression ignition (MCCI).

The reviewer observed that Task 2 neutron imaging development for engine applications is making progress, as evidenced by the new 2x-3x resolution detector. This is more of an open-ended research project in that there is not a precise problem to be solved here, but rather many areas where this unique capability could be used. The reviewer found the combination with Task 1 to be really encouraging and also suggested combining it with more traditional industry temperature measurement techniques. It is unclear if all the neutronic engine efforts fall into this Task 2, but this progress is also very encouraging.

According to the reviewer, Task 3 looks to have made significant progress based on the engine data and the control authority evaluation at low-load GCI between PFS and high fuel stratification (HFS). Despite this progress, the reviewer really struggled with GCI enabling MD and HD fuel efficiency as 50% EGR is not a real solution for the industry. The reviewer thought that this whole GCI strategy needs to be mapped out, considering the electrification in Task 4. The reviewer asked if the project team can articulate where the project will run GCI with reasonable EGR levels (less than 25%), where the hybridization will take over, what the full-load GCI strategy looks like, and how the project will idle the engine with GCI. These are the challenges the industry needs help with more than incremental fuel consumption improvements by burning gasoline instead of diesel fuel.

Task 4 has also made great progress, with four different data sets having been completed and the upcoming publication. This progress shows useful data for benchmarking and strategy development. The reviewer opined that the comments about engine calibration and thermal management of aftertreatment and the interaction with the hybridization and start-stop are correct. It is curious as to why the NO_x is lower on the hybrid plus start-stop than the hybrid, given the lower exhaust temperatures. It is also curious the hybrid plus start-stop has more fuel economy gain than the conventional start-stop has.

Reviewer 4:

The reviewer observed good progress on all fronts. Understanding hybridization and stop-start impacts on emissions is important. The reviewer wanted to know if hybridization can be used to improve cycle emissions, whether stop-start improves or degrades emissions performance, and how the fuel consumption benefit of stop-start is impacted if co-optimizing for emissions as well.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found outstanding collaboration across the broad-based project team, which includes national laboratories, universities, and industry partners and praised the collaboration as well done.

Reviewer 2:

Collaboration and communication among team members appeared outstanding to the reviewer. The projects have been well supported by each partner, and there appears to be excellent coordination among team members, even among people at different labs and different organizations.

Reviewer 3:

There is very clear collaboration between the many teams, and this is one of the benchmark examples for VTO, according to the reviewer. The leveraging of the labs, industry, and past industry projects is clearly collaborative and intentional.

Reviewer 4:

There is a large body of diverse work with multiple participants and supporting team members. The reviewer applauded the good job keeping this work all coordinated with good progress this year.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

This is the last year for the project, and the team has some tasks that need to be completed in FY 2021 to meet the defined goals. The reviewer suggested that the team please continue to work in a collaborative manner to get over the finish line.

Reviewer 2:

The reviewer stated all four tasks have clear paths for future research to complete the milestones and deliverables.

Reviewer 3:

The reviewer said most of the proposed future work appears to be relevant and sensible. Task 3 might be better focused on the suggestions highlighted in the previous comments for Approach.

Reviewer 4:

As stated previously, the GCI work should be laid out versus a SOA diesel comparator. The reviewer asked if emissions aftertreatment requirements are the same at lower efficiency and what is the "why buy"? The reviewer encouraged an expansion of Task 4 to include the overall benefits of hybridization to criteria emissions as well as fuel consumption.

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

Reviewer 1:

According to the reviewer, the project will play a critical role in advancing the foundational knowledge base for the next generation of MD and HD engine systems. It has developed critical enabling technologies that have been leveraged in some of the other projects like the 21st Century Truck Partnership, which supports the overall DOE objectives to decarbonize transportation across all modes as well transition to a clean energy economy.

Reviewer 2:

The reviewer remarked that the project is highly relevant to DOE goals for MD and HD engines and vehicles and addresses fundamental understanding and practical applications.

Reviewer 3:

There is clear relevance for these projects as they are aligned with the VTO lab call and the 21st Century Truck Partnership. Given the new VTO budget and the orientation of on-road work toward electrification, the reviewer proposed focusing the application of these tasks away from on-road and toward off-road, marine, and rail applications.

Reviewer 4:

Neutron imaging, in the reviewer's opinion, is less relevant due to the limited availability of this type of resource and may only be usable as a last resort if all other methods have failed to address the issue.

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

Reviewer 1:

The reviewer said the project is projected to be completed on budget.

Reviewer 2:

Based on the broad scope and quantity of work, it seemed to the reviewer that resources are adequate.

Reviewer 3:

Looking at the results and the opportunity for future progress, the reviewer opined that the project could use some additional support.

Reviewer 4:

The reviewer said there is not an issue with time, money, people, or facility resources projected that would inhibit the upcoming deliverables. Of course, more can always be done, and the reviewer urged DOE not to reduce this funding and to help support the project to transition toward more off-road applications.

Presentation Number: ace138
Presentation Title: Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium
Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

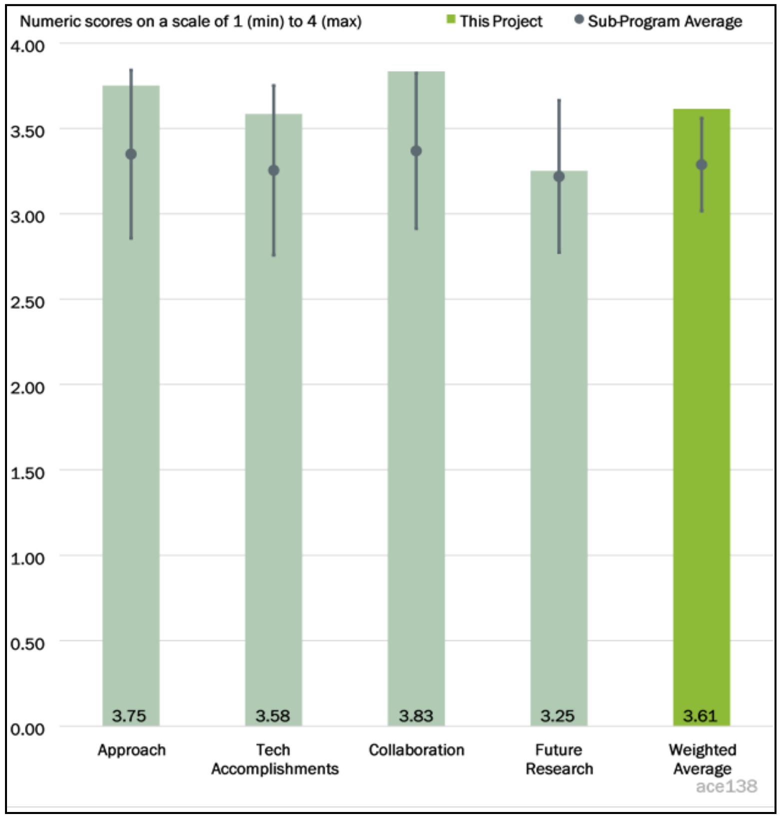

Figure 1-18 - Presentation Number: ace138 Presentation Title: Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

Presenter

Matthew McNenly, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 is critical work for the industry and the collaboration between labs has already led to breakthrough results. The reviewer expected that this project will continue to make significant improvements in simulation tools.

Reviewer 2:

The reviewer observed that the approach is aligned with industry priorities and is partnering with major software vendors by leveraging DOE investments in high performance computing (HPC), machine learning (ML), and artificial intelligence (AI).

Reviewer 3:

This is a comprehensive approach to addressing problems that, when solved, will have a direct impact on efficiency and emissions. The reviewer noted that major outcome 7, LTC combustion metrics, is out of project, which is good.

Reviewer 4:

The reviewer remarked that the PACE project has the technical targets of addressing limits to SI engine efficiency (e.g., knock and LSPI); the barriers to highly dilute combustion; and emissions reduction during cold start. These are all research areas that are high priorities for industry. Through its open-source models, the reviewer asserted that this project has a direct path to impacting industry workflows. The project is well designed, feasible, and there is very little concern that it will not meet its goals. The reviewer's concern at this point is that the funding may be reduced (or cut) going forward due to updated DOE priorities, which would be unfortunate and a missed opportunity to ensure the most efficient and cleanest engines going forward.

Reviewer 5:

The reviewer said the work is sharply focused and appears to be in-sync with the industry stakeholder needs. It is an excellent project; however, within the time frame for which this project is focused, the need for even larger reductions in CO_2 emissions from the mobility sector (in addition to maintaining very low criterial pollutants) will likely be demanded. Engine efficiency improvements alone with be insufficient to accomplish the needed CO_2 reduction. Life-cycle analyses—which are dependent on the boundary conditions and assumptions— indicate that when electricity generation, mineral extraction, and production processes required for the large increase in electrified vehicles are considered, the CO_2 reduction of large-scale electrification may not be as large as currently assumed. It seemed to the reviewer that it would be prudent to couple the activities of the Partnership for Advanced Combustion Engines (PACE) with the need for introduction of lower carbon fuels. The reviewer wanted to know if one examines likely scenarios where reduced carbon fuels could start to be introduced into the market, will the operating constraints or boundary conditions for the engine change? Will PACE activities need to be modified in such scenarios? Personally, the reviewer did not think that the idea of e-fuels should be dismissed so quickly, which is another discussion completely.

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:

Given the COVID pandemic, this reviewer believed that the technical accomplishments and progress have been remarkable. Most of the milestones were delivered on time.

Reviewer 2:

The reviewer found good progress getting the new engines installed in test labs.

Reviewer 3:

According to the reviewer, steady progress was made despite COVID-19 delays.

Reviewer 4:

The focus is on two DOE exascale computing program codes, namely NEK5000 and Pele. It was not clear to an outside reviewer what the focus is of each of these codes.

Reviewer 5:

The reviewer stated the results reported are impressive, and the effort to make the computation tools available to the stakeholders as quickly as possible seems to be robust. However, the reviewer was concerned about the results shown in Slide 17, or perhaps the reviewer did not understand the reporting of them. Slide 17 says, "Success measures are for the predicted accuracy of the target for a design change with fixed model parameters," in which case, the 10% and 20% success rates seemed quite low to the reviewer. The plots show reasonable agreement between the experimental mean and the model prediction mean, but the experimental outliers are quite significant; there is a large difference between the spread in the variability in the engine cycles versus the CFD cycles. The reviewer thought that the extreme variations of the experimental data would likely have the most adverse impact on such things as emissions and inquired if this means the simulation needs to be tuned for each design change. If so, it will be a hinderance to analysis-led design.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the work is very complete and seems to be synergistic.

Reviewer 2:

The reviewer found the collaborations between labs, experimentalists, and simulation teams to be excellent.

Reviewer 3:

The reviewer noted that this project is a shining example of how the labs can work together to achieve DOE goals, with ANL, Lawrence Livermore National Laboratory (LLNL), NREL, ORNL, and Sandia National Laboratories (SNL) all part of this project. This project also has collaborations with software vendors, universities, and the OEMs themselves.

Reviewer 4:

The reviewer commented that adding CONVERGE in FY 2020 is good.

Reviewer 5:

The reviewer said most of the OEMs, commercial-off-the-shelf (COTS) software vendors, universities, and labs are involved with the project to leverage the work being done.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer referenced earlier comments in Technical Accomplishments regarding lower carbon fuels.

Reviewer 2:

This reviewer described future work for this project as well laid out. Of particular interest is the website that will include models, mechanisms, best practices, etc., to provide the developed resources to all stakeholders.

Reviewer 3:

The reviewer stated the project plans are good and take into account simulation needs of OEMs customers.

Reviewer 4:

The proposed future research topics related to closer coordination and enhancing industry software adoption are very well planned. It was not clear to the reviewer what the project team means by building partnerships with other DOE offices, including BES.

Reviewer 5:

The reviewer encouraged the team to continue to pursue project objectives. Providing improved and validated simulation tools to the industry will directly impact engine design and calibration, leading to improved efficiency and emissions.

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

Reviewer 1:

The reviewer affirmed that, yes, the project support addresses the overall DOE objectives and referenced previous comments about considering lower carbon fuels.

Reviewer 2:

The reviewer stated the project supports the overall DOE objective because the focus of the research is to maximize engine efficiency and lower emissions.

Reviewer 3:

Project results will have an immediate impact when employed by OEMs, according to the reviewer.

Reviewer 4:

The reviewer remarked that improved simulation tools will lead to better engines with reduced fuel consumption, achieving DOE goals.

Reviewer 5:

The reviewer indicated that yes, this project supports the overall DOE objectives of producing more efficient and cleaner propulsion systems.

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

Reviewer 1:

The reviewer stated the PACE project is poised to make a real, substantive impact on improving engine simulation capability, and resources should be increased so the goals can be achieved sooner.

Reviewer 2:

This reviewer believed that the resources are sufficient and hoped that funding would not be reduced going forward as this is a very important project.

Reviewer 3:

The reviewer said the project team has curtailed work on some of the original objectives in order to make faster progress on higher priority objectives. The project is managing the resources provided well.

Reviewer 4:

Based on the information presented, the reviewer was not completely sure whether the project has access to sufficient computational resources.

Reviewer 5:

The reviewer encouraged continued funding of this project and expressed concern that FY 2022 budget cuts will diminish the project.

Presentation Number: ace139
Presentation Title: Chemical Kinetic Models for Surrogate Fuels
Principal Investigator: Scott Wagnon (Lawrence Livermore National Laboratory)

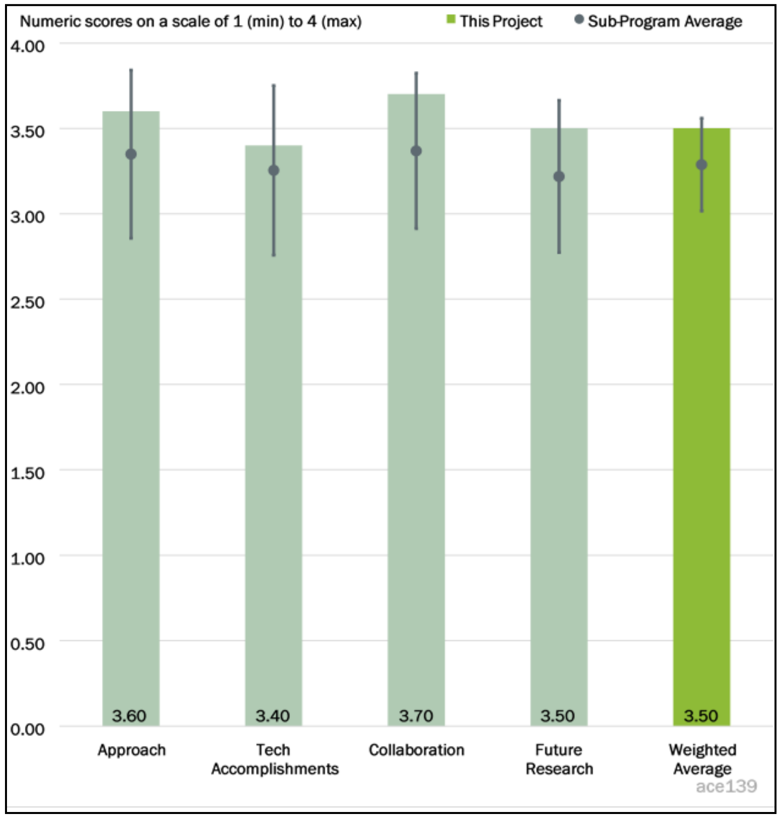

Figure 1-19 - Presentation Number: ace139 Presentation Title: Chemical Kinetic Models for Surrogate Fuels Principal Investigator: Scott Wagnon (Lawrence Livermore National Laboratory)

Presenter

Scott Wagnon, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 has clearly identified barriers and cross-functional groups to address the challenges.

Reviewer 2:

The reviewer said reaction mechanisms and kinetic models are crucial for an in-depth understanding of the combustion processes, such as low-speed pre-ignition (LSPI) and cold-start emissions. This capability requires combined efforts to develop surrogate fuel, mechanisms, data for model validation, and mechanism reduction for an accurate engine simulation. According to the reviewer, the project is very well designed to cover these areas.

Reviewer 3:

Understanding fuel combustion kinetics and complex interactions between engines and fuel combustion dynamics continues to be an impediment to further development of higher efficiency engines, both SI and CI, that are being researched by DOE and designed by OEMs. The reviewer remarked that the projects reviewed here continue to provide insight into kinetically controlled systems that are critical to engine performance—fuel auto-ignition reactions, fuel reactions leading to soot formation, and the ability to describe real fuels through chemical surrogates. The approach taken in the projects—to obtain high-quality experimental data that are directly based on kinetically controlled systems with a minimum of confounding factors to be subsequently used for kinetic model development— is a tried-and-true model that the reviewer indicated has steadily led to greater and greater understanding of combustion kinetics.

Reviewer 4:

The reviewer asserted that there are not enough real engine experiments to validate some of the directions of the research when considering "trial and error" is still used to find the components that "best" capture fuel behavior in real engine applications.

Reviewer 5:

The project focuses on the development of surrogate and subsequent kinetic models of PACE-1 and PACE-20. Following a classical approach, the reviewer noted that the models are comprehensively validated against engine and fundamental kinetic targets, such as ignition delay, flame speed, crank angle at 10% mass fraction burned (CA10) in engine conditions, and soot volume fraction. In general, very good confidence has been achieved for the application of these models for all potential users. One issue the reviewer had regarding this surrogate approach is on its generality when applying to other fuels. The current surrogate approach is on a trial-and-error basis and largely relies on the fuel components. It will be very nice if a general strategy can be developed to more systematically and quickly generating surrogates for novel alternative fuels. The reviewer remarked, furthermore, it will be tremendous if a surrogate model can be developed based on the desired fuel and engine properties without focusing on the fuel type and structure, if achievable.

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 project made significant progress in (1) defining and sharing the surrogate fuel, PACE-20, for all tasks, (2) developing and validating reduced kinetic models for PACE-20 and toluene primary reference fuel (TPRF) - 10% ethanol, 90% gasoline blend (E10) for engine simulations, (3) releasing an improved detailed gasoline surrogate model to consortium members, and (4) having new data for surrogate fuels and complex research-grade regular E10 gasoline (RD5-87).

Reviewer 2:

The reviewer asserted that there are not enough real engine experiments to validate some of the directions of the research when considering "trial and error" is still used to find the components that "best" capture fuel behavior in real engine applications.

Reviewer 3:

Overall, the progress and accomplishments are good. The reviewer made the following points:

- On Slide 9, the reviewer was not sure if the maximum error of 12.6% is acceptable, even though the presenter mentioned that it is acceptable. Perhaps a sensitivity study to figure out the "kinetic model reduction" versus "accuracy" trade-off is needed.
- On Slide 10, there must be a reason why the verification was not done over phi=1 for 10%, 20%, and 30% EGR levels. Please explain.
- On Slide 11, the reviewer said the ignition delay time at low-pressure level exhibits negative-temperature coefficient (NTC) behavior, while the model does not reproduce well.
- On Slide 12, the LLNL detailed model shows deviation from measurements. Is it possible to comfortably say that the detailed chemistry is the "golden" reference for developing a reduced mechanism?

Reviewer 4:

The reviewer stated continued progress on the science and art of developing fuel surrogate models, validating and refining models under lean combustion conditions, and implementing best practices for mechanism reduction all demonstrate good technical progress. Laminar burning velocity studies and insights will become more and more critical as SI engines continue to move toward dilute conditions for higher efficiencies.

Reviewer 5:

The reviewer observed that the accuracy of surrogate and kinetic models has been thoroughly validated against different kinetic targets through direct comparison; the technical accomplishments and progress toward the overall project are satisfactory and can substantially benefit other teams. New measurements of fundamental and engine targets have been acquired, and the models can reproduce the target reasonably well. A minor concern is that the size of the kinetic model is still quite large and includes more than 300 species, which is too large for practical engine and combustion simulation and will be addressed in the future work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer praised the collaboration and coordination across the project team as outstanding, with more than 15 partners across industry, academia, and national laboratories. The results can benefit many teams within and beyond the project.

Reviewer 2:

The reviewer thought the collaboration is great.

Reviewer 3:

The reviewer observed that many entities involved in the project collaborated well toward project goal.

Reviewer 4:

The reviewer stated the project includes a number of collaborators that are well integrated with the project's efforts.

Reviewer 5:

The reviewer said collaborations across the national laboratories and universities help provide this effort with a wealth of experimental data to draw from when developing and validating models. One area that seems to be less well represented from the collaboration list is specific collaborations with industry that demonstrate these models are able to be used by industrial 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said the proposed future research has logical next steps.

Reviewer 2:

The reviewer stated the future research is well planned to continue characterizing the RD5-87 and the surrogate fuel, PACE-20; collecting data using the ANL rapid compression machine (RCM) and other fundamental devices and engines for model validation; using new analytical and computational approaches to rapidly establish and implement more accurate models of the important surrogate fuel chemistry; and working with the LLNL numerics team to quickly reduce kinetic models to deliver to PACE members and industry.

Reviewer 3:

The reviewer said the proposed future work continues to push the boundaries of knowledge in key areas—heat release and autoignition phenomena in lean mixtures, impacts of EGR constituents on combustion kinetics, and fuel kinetics in oxygen-deficient environments leading to soot precursors.

Reviewer 4:

The reviewer thought that it may be worthwhile going back to the detailed model and trying further improvement of its accuracy.

Reviewer 5:

The reviewer acknowledged that the proposed future research involving lean-dilute EGR, cold-start conditions is certainly relevant and interesting, and a further reduced mechanism with similar accuracy is also urgently needed. In addition to a more general approach for surrogate model development, one extra aspect that merits future investigation is the uncertainty quantification of the model, which can be evaluated through either Monte Carlo or a Bayesian type of analysis. According to the reviewer, both the model and the experimental target will inevitably contain uncertainties, which should be considered when comparing the modeling with the experimental target. A useful set of experiments will help to further reduce the uncertainty of the model.

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

Reviewer 1:

The reviewer stated the project's relevance to overall DOE objectives is outstanding.

Reviewer 2:

The reviewer indicated that fundamental fuel combustion research is the foundation of developing advanced clean and high-efficiency engines, and its contribution to support the overall DOE objectives should not be underestimated.

Reviewer 3:

The reviewer said the reviewed projects drive knowledge and insights that ultimately lead to higher efficiency and lower emissions engines, a key DOE goal.

Reviewer 4:

The reviewer observed that developing chemical kinetics for surrogate fuels is an important step in making more efficient engines with lower emissions.

Reviewer 5:

The reviewer said the project supports the DOE objectives to reduce carbon footprint by advancing technologies for more efficient and robust ICE development.

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

Reviewer 1:

The reviewer said the project's resources are okay for the scope.

Reviewer 2:

The reviewer stated the project seems to have enough resources to achieve the stated milestones.

Reviewer 3:

It looked to this reviewer like the project has sufficient resources to achieve the stated milestones.

Reviewer 4:

There are sufficient resources to achieve the stated milestones, according to the reviewer.

Reviewer 5:

The reviewer said these projects are appropriately resourced, allowing the projects to fund collaborations that provide key validation data in the areas of ignition delay, flame speed, sooting tendency, etc. Reducing resources to the point these external collaborations could not be funded would significantly hinder the further development of kinetic models.

Presentation Number: ace140
Presentation Title: Accelerated Chemistry and Transport for Engine Simulations
Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

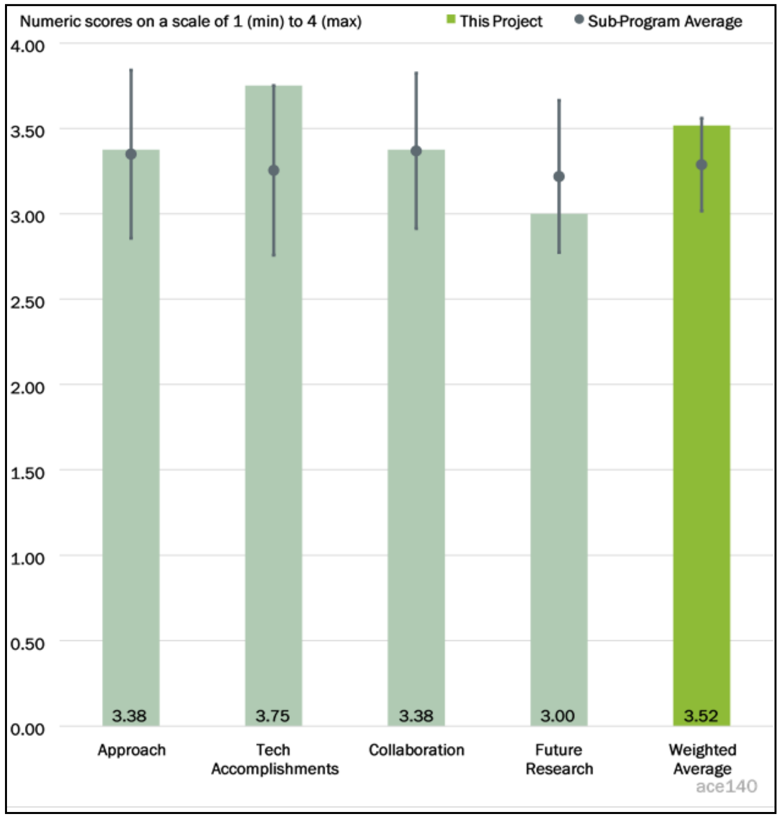

Figure 1-20 - Presentation Number: ace140 Presentation Title: Accelerated Chemistry and Transport for Engine Simulations Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

Presenter

Russell Whitesides, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 50% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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:

According to the reviewer, the project is a very creative approach to identifying further pathways to speed up chemistry solvers.

Reviewer 2:

The reviewer stated it is a very solid approach for developing, optimizing, and deploying to partner labs. The fundamental detailed chemistry was either reduced or optimized or directly evaluated for CFD simulations.

Reviewer 3:

For HD diesel engines, the reviewer indicated that the pressure and temperature range need to be extended beyond what is mentioned in the approach. For high engine load conditions, cylinder peak pressures are reaching about 250–300 bar, and the reviewer wanted to make sure the proposed chemical kinetics perform well for these conditions.

Reviewer 4:

Key technical barriers for engine simulation tools are clearly defined, but the key technical barriers specific to this project were less clear to the reviewer. Advancement of computational tools is an understood goal, but more clarity on specific barriers at the project level would be useful to gauge the impact of this project.

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 it amazing that further speed-ups in chemistry have been realized.

Reviewer 2:

Technical accomplishments related to kinetic rate parameter optimization framework, Zero-Order Reaction Kinetics (Zero-RK) implementation in Nek5000 and Pele, and rate optimization are significant, according to the reviewer.

Reviewer 3:

The reviewer said developed methods have been coupled to chemistry tools to accelerate engine CFD simulations, which is definitely an area of interest for the industry. With the number of species less than 100, the speed-up is still pretty decent. At this stage, the reviewer noted that the industry still uses relatively smaller chemical mechanism due to computational efficiency. The speed-up of chemistry calculation will be well received.

The speciation information is very interesting for developing a solid chemical mechanism. The reviewer emphasized that it is impressive to learn the mechanical reduction can be done in under one hour and called the research a great job. This would be welcomed by the community. It is interesting to see the practice of adjusting rate parameters for CFD simulations. The reviewer wanted to know what the basis of adjusting is and if there is any bond for adjusting ranges.

Reviewer 4:

Overall, the reviewer noted, progress is being made toward delivery of the milestones. The 2020 milestones were completed, but it was less clear to the reviewer where the progress in 2021 will be, with a delayed Q1 milestone and lower clarity on progress toward later-year milestones. From technical data presented, it appeared to the reviewer that the team is making significant strides in performance. End-user impact of this project's current effort is less concretely shown.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said collaborations between the national laboratories has been very productive and the collaboration with commercial simulation software providers provides a pathway for industrial utilization.

Reviewer 2:

Collaborations between the project team and others appeared to the reviewer to mainly focus on implementing the developed tools on other national laboratory systems and used by other national laboratory project teams. This focus, to roll out the tools to other researchers, is laudable. At the same time, it was less clear to the reviewer that there are collaborations that help to advance the efforts of this specific project.

Reviewer 3:

The collaborations slide is a comprehensive list of PACE and national laboratory staff, and commercial vendors, but the reviewer would like the PIs to have included other vendors, such as Ansys, Inc., and Siemens.

Reviewer 4:

The reviewer stated the collaboration was well connected to different parties. There is an indirect link to the industry through partners, and the reviewer strongly suggested a direct industry application, i.e., leveraged by an industry partner to product development.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer opined that the project has a clearly defined path forward.

Reviewer 2:

Kinetic rate parameter optimization and specific items mentioned under detailed kinetics in scalable combustion CFD are highly relevant, according to the reviewer.

Reviewer 3:

In addition to what has been proposed, an industry adoption case would be very interesting to the reviewer.

Reviewer 4:

The reviewer stated another 2x speed-up would be great.

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

Reviewer 1:

The reviewer asserted that improved simulation tools help engine developers design more efficient engines, reducing energy usage.

Reviewer 2:

The reviewer stated this topic is highly relevant for fuel efficiency and emissions, which is a high priority for the DOE.

Reviewer 3:

According to the reviewer, chemical kinetics are an important area for advanced engine concept exploration. It is a big knob to be able to get predictions right and to be predictive. Its development, reduction, and optimization will be highly relevant.

Reviewer 4:

The reviewer commented that improving computational techniques for engine combustion development is a key element of DOEs objectives for improving ICE efficiency and developing tools for industry to leverage to do so. At the most fundamental level, efforts to improve models and speed up solvers are aligned with that mission.

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

Reviewer 1:

From the technical achievement and progress, the resources were reasonable to the reviewer.

Reviewer 2:

The reviewer opined that the project is critical work that should be accelerated with additional resources.

Reviewer 3:

Chemical kinetics and algorithms are very important for accurate and faster engine simulations. Compared to other VTO efforts, the reviewer warned that this effort is relatively underfunded.

Presentation Number: ace141
Presentation Title: Advanced Ignition Barriers Research
Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

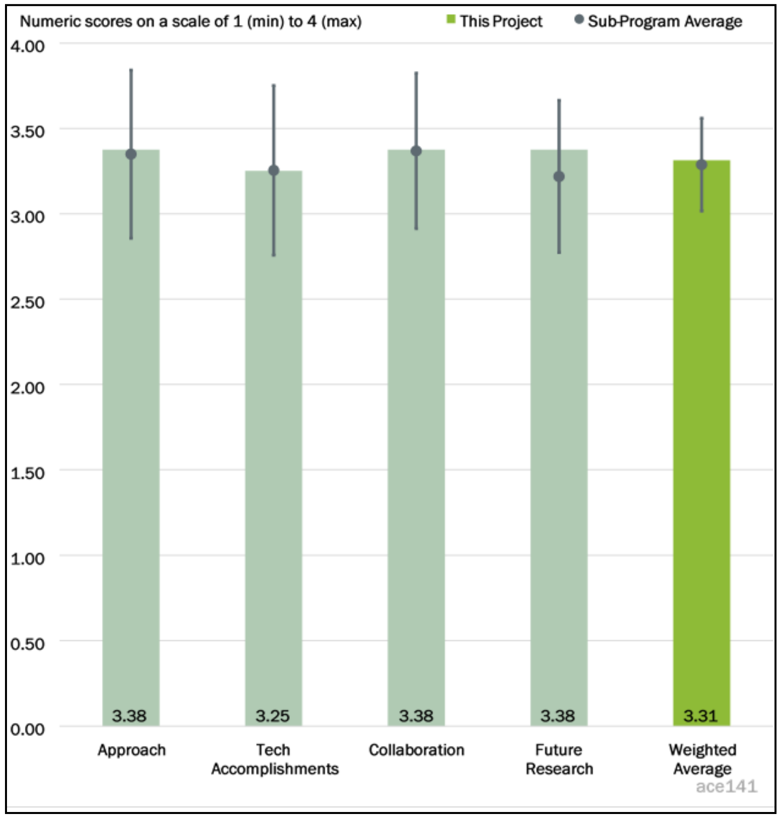

Figure 1-21 - Presentation Number: ace141 Presentation Title: Advanced Ignition Barriers Research Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

Presenter

Isaac Ekoto, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 the fundamental approach to examining the potential for ignition technologies continues to bring new and valuable insights.

Reviewer 2:

The reviewer found that the approach is sound and addresses most technical barriers.

Reviewer 3:

According to the reviewer, the overall approach to this work is excellent, and the focus on steady-state, high EGR conditions and catalyst light-off conditions are very intelligent choices. The modeling and experiments are well planned and well approached.

A suggestion for future improvement from the reviewer would be to establish logic or a workflow for narrowing the technologies down or identifying the most promising technologies. As it stands, much of the work seems more like a screening effort for which the next step would be to use fundamentals or experimental results to prioritize technologies and guide their future development. The reviewer said, for example, if the 0%–10% burn duration is too long, that may explain the stability issues seen. Therefore, if a technology exhibits a 0%–10% burn duration that is too long, the team can either eliminate it or return to fundamentals to clearly outline what is or is not possible to improve it. The reviewer said a broader framework for evaluating and developing the technologies would be the ultimate goal.

A final comment from the reviewer is that the use of abbreviations in the presentation was a bit confusing and, in the future, fewer abbreviations and/or clearer reminders of what the abbreviations stood for would be immensely helpful.

Reviewer 4:

This reviewer asked whether the PI believes one-dimensional (1-D) modeling of the pre-chamber (PC) throat flow is sufficient to capture the trapped mass and overflow behavior. In particular, does the PI believe the model properly captures subsonic versus possible sonic flow into the PC?

Concerning indicated thermal efficiency (ITE), what is the uncertainty? In some figures, different EGR rates with different ignition strategies were compared and contrasted, which showed small differences on the ITE. The reviewer also asked how well the plasma kinetics were validated before applying them to the overall plasma modeling effort. Regarding experimentally indirectly determining flame speed (S) and time (t), how did the PI address heat losses? What is the uncertainty in estimating this heat loss?

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:

Progress made since last year has been quite good, and the reviewer said that it addressed many of the comments from last year, also.

Reviewer 2:

According to the reviewer, good progress has been made, overall.

Reviewer 3:

The reviewer found the technical accomplishments in all areas to be impressive. It would really help to show very clearly how the efforts interconnect with one another to ultimately put forth a technology that is most promising.

Reviewer 4:

There seem to be a few sources of uncertainty in the modeling and experimental work that were not addressed in the presentation. Possibly the PI has already addressed these concerns in the past. The reviewer stated, directionally, this effort is addressing some barriers to lean combustion at cold conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said very good collaboration exists.

Reviewer 2:

The reviewer noted that the project is largely within Sandia, but the interactions with the partners have been quite effective.

Reviewer 3:

According to the reviewer, the effort appears fairly well coordinated within PACE, and the external collaborations are good. It would be excellent to see OEM involvement, if possible.

Reviewer 4:

The project fits well into a much larger, multi-organizational project addressing DOE needs in the IC area. The reviewer commented that one apparent missing element was direct university participation. There appears to be indirect participation, and possibly this makes sense for this particular project, though it is worth a discussion.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said future plans continue to consider key questions for industry.

Reviewer 2:

The proposed research is very sound and logical to the reviewer. The focus on the cold start catalyst light-off conditions will be very interesting as the project will pose some unique challenges (e.g., very high in-cylinder temperature conditions). As noted previously, the reviewer asserted that it would be good to explicitly state how the various efforts interconnect and how the modeling and experiments ultimately support one another.

Reviewer 3:

One suggestion from the reviewer is to closely look at the 1-D model for the PC case and consider if it is accurate enough for the purposes of this project while also considering a two-dimensional (2-D) model. Also, if it has not occurred yet, taking another look at validating plasma dynamic kinetics might be worthwhile.

Reviewer 4:

The reviewer stated more emphasis should be placed on passive PC ignition.

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

Reviewer 1:

These efforts aim to enable more efficient, lower emitting engines, and thus the reviewer indicated that they are very well aligned with DOE objectives.

Reviewer 2:

The reviewer stated the project directly supports lean combustion R&D by exploring different possible strategies to attain this goal at cold, low-load conditions with a possible extrapolation to higher load conditions. In particular, it supports improving IC engine ITE at part-load conditions and has shown some promise of allowing quite lean operations, though results are early and much work is ahead for other PIs and associates.

Reviewer 3:

According to the reviewer, the project supports DOE objectives to reduce petroleum consumption.

Reviewer 4:

Despite changes in DOE budget priorities, the reviewer opined that advanced ignition will still be needed for ongoing mobility efficiency gains.

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

Reviewer 1:

The budget appeared good to the reviewer for the work scope as planned.

Reviewer 2:

The reviewer stated the project resources are appropriate to complete the planned work within the planned timeframe.

Reviewer 3:

The resources, both experimental and modeling, are sufficient to the reviewer.

Reviewer 4:

The reviewer had no comment.

Presentation Number: ace142
Presentation Title: Development and Validation of Predictive Ignition Models
Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

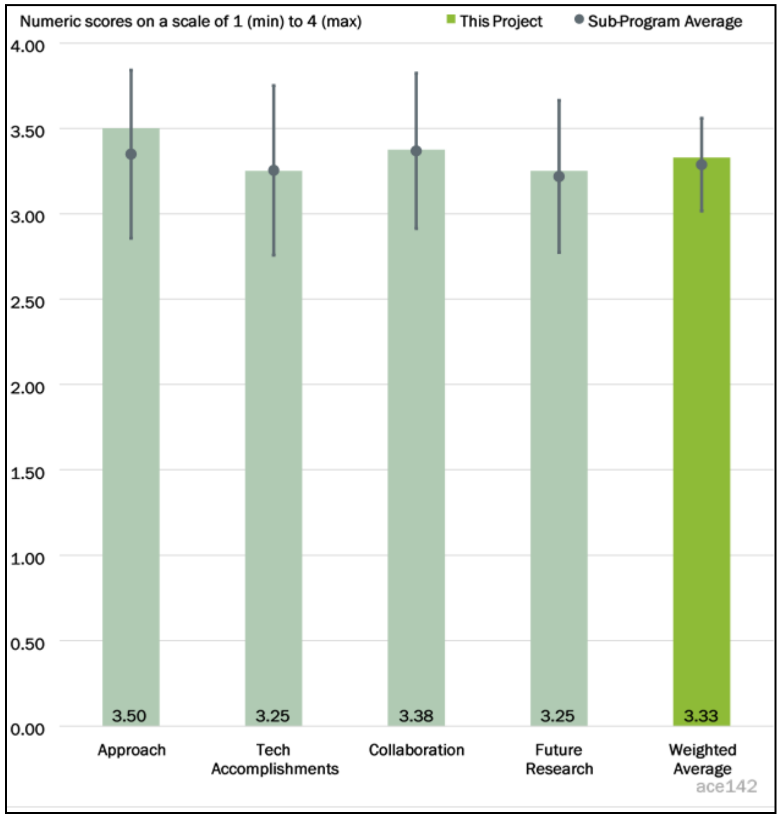

Figure 1-22 - Presentation Number: ace142 Presentation Title: Development and Validation of Predictive Ignition Models Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

Presenter

Riccardo Scarcelli, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 there are many good connections between different steps in the modeling as well as the experiments. The different steps integrate well, and all support the overall goal of the project. The outcomes are integration of the models into CONVERGE and into user defined files (UDF) that can be implemented into commercial codes in industry. According to the reviewer, the only potential step missing is validating the UDFs in the commercial codes against the wealth of data that will be produced in the project. The UDF and spark process itself will be validated, but how these processes tie into subsequent flame propagation or the mixing both before and during the ignition process will likely be dependent on the models in the code. The reviewer noted that, by integrating directly into CONVERGE, the integration might be smoother there since everything can be integrated together.

Reviewer 2:

The reviewer asserted that predictive ignition models are extremely important for advanced SI combustion modes that are being evaluated by industry for improving efficiency and reducing emissions. This fact is particularly important for lean (air) and dilute (EGR) SI and cold-start predictions. The reviewer opined that evaluating and updating models such as G-Equation, extended coherent flame model (ECFM), etc., are critical.

Reviewer 3:

The reviewer stated the research approach should be independent of any one specific CFD vendor so the research had wider acceptance.

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 experimental and computational accomplishments shown at different operating conditions is very impressive.

Reviewer 2:

According to the reviewer, technical accomplishments for the year are all individually impressive. Comparisons of spark kernel growth between the CONVERGE implementation and experiments are improving. Improved understanding from direct numerical simulation (DNS) may continue to help match the experiments and simulations. The PI provided a helpful answer about boundary conditions in the talk during AMR. Improvements in the sampling for ML models are good; the reviewer suggested that it would be excellent to see this work published as this is going to be a common issue for folks taking high-fidelity data sets and developing models using ML. The current comparisons between the DNS and ML results are good, although it will be interesting to see how far the ML is able to capture “limiting” events at less optimal operating conditions. The reviewer observed that it would be nice to see this integrated into the workplan, since prediction of misfire, incomplete combustion, etc., will be critical to the success of these models. The new crossflow experimental facility looks very nice and initial results look promising. Using discharge molecular tagging velocimetry (DMTV) will be challenging; it would be good to consider uncertainties with the technique, which may be difficult to quantify, but the reviewer agreed that particle image velocimetry (PIV) is not a good option. It will be interesting to see these comparisons with large eddy simulation (LES) and DNS at non-quiescent conditions, which is progressing nicely. The focus on cold start is an important step and the initial results looked promising to the reviewer in comparison with the experiments. Capturing the potentially wide variability at these conditions will be important.

Reviewer 3:

The overall progress of the project seemed fine to the reviewer. What the reviewer felt is lacing from the AMRs is the depth in validation of these models. Granted that lack of depth cannot be shown in a 30-minute presentation, additional material of the how the models perform over a wide range of lean and dilute and cold-start conditions should be shown. For example, the reviewer wanted to know how many varieties of cases were simulated and how the results aligned with the experiments. A summary of those with statistical analysis would have been useful to include in these presentations. It was also a bit unclear how the knowledge from DNS is used for model development (a statistical analysis of DNS data task in the future is seen, but more information on this topic will be helpful). The reviewer inquired about whether the model predicted flame speeds (both laminar and turbulent) and those obtained from DNS can be compared and correlated to guide whether the flame propagation is well established.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said only one COTS CFD vendor is included but including other software vendors will make for wider acceptance of the sub-models.

Reviewer 2:

The reviewer observed good collaboration between the team members, but as mentioned before, the role of the DNS work for model improvement is a bit vague.

Reviewer 3:

There are good collaborations within the labs, and the collaborations within the CRADA also seem strong. Connections with CONVERGE are very good, and integrating the new models seems to be going nicely. The reviewer referenced previous comment on the UDFs for other collaboration piece. While the PACE framework provides a good model for passing the UDFs to industry, it was not clear to the reviewer how much work is going to be done to test other codes (not CONVERGE) against the data collected at the labs and in the CRADA, which may be an issue if other sub-models within the commercial code interact with this UDF strongly.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future work outlined on Slide 21 for three different conditions is informative. It was not completely clear to the reviewer how the priority is determined for these three conditions.

Reviewer 2:

The reviewer indicated that the future work plan is well laid out and the foundations for all the remaining steps are in place.

Reviewer 3:

The reviewer asserted that the future work should not focus on methane/air mixtures, but on gasoline.

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

Reviewer 1:

According to the reviewer, the industry needs predictive ignition models for prediction of knock, capture misfire, and ignition at highly stratified conditions.

Reviewer 2:

Tight integration of this effort within the PACE framework ensures it is meeting overall DOE objectives. The PI has demonstrated to the reviewer how these results are critical to overall engine modeling outcomes, and the integration with industrial codes ensures a wider impact going forward.

Reviewer 3:

The reviewer affirmed that, absolutely, this work is exactly the kind of work national laboratories should be doing and helping the industry with. It perfectly aligns with DOE's mission.

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

Reviewer 1:

The resources seemed sufficient to the reviewer, especially given there was a new experimental facility brought online in the past year.

Reviewer 2:

The resources seemed to be sufficient to the reviewer to proceed with this work.

Reviewer 3:

The reviewer commented that additional computational resources may be needed for DNS simulations.

Presentation Number: ace143
Presentation Title: Fuel Injection and Spray Research
Principal Investigator: Chris Powell (Argonne National Laboratory)

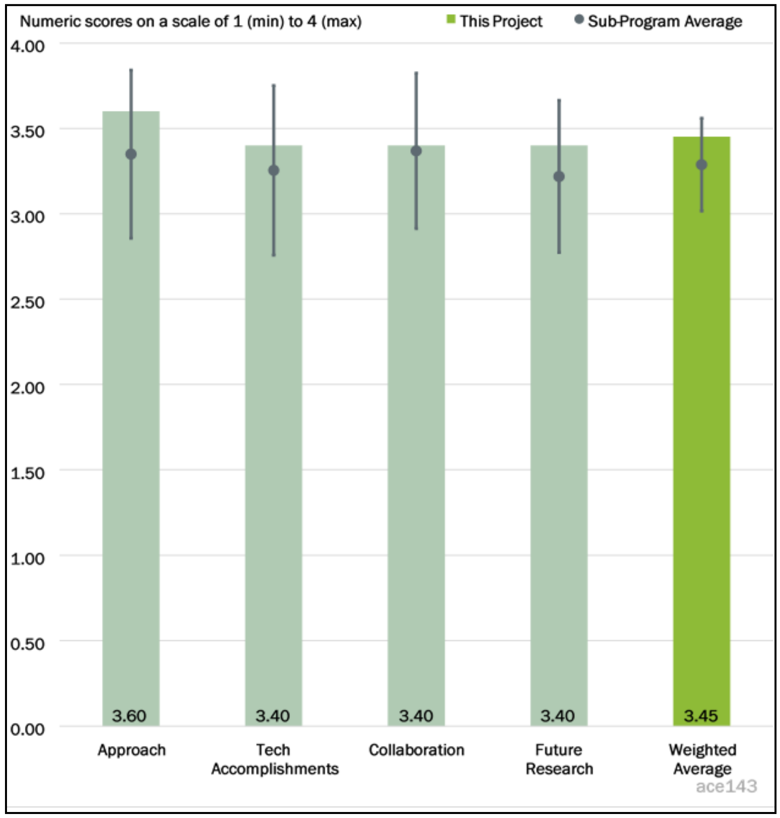

Figure 1-23 - Presentation Number: ace143 Presentation Title: Fuel Injection and Spray Research Principal Investigator: Chris Powell (Argonne National Laboratory)

Presenter

Chris Powell, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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:

A multi-pronged approach of the various national laboratory partners (both modeling and experimental) and sensible separation of tasks by spray type (free, wall interaction, etc.) are hard to improve upon, according to the reviewer. Thankfully, the team is switching to more modern injection hardware. Creating a merit function is a worthy objective.

Reviewer 2:

The reviewer indicated that the team has an excellent mix of experimental and simulation work. There has been remarkable progress in expanding the capability of diagnostics, as evidenced by the three-dimensional (3-D) SNL liquid volume fraction (LVF) work, which complements the ANL mass distribution work quite nicely. The simulation work also appears to be rapidly catching up to the experimental advances, with LES improving the predictions quite well. The concept of developing a merit function was also highly desirable to the reviewer, although this will be challenging as it will require deciding whether the merit function definition is strictly for spray parameters or if engine parameters would be incorporated—for example, any in-cylinder swirl/tumble, the density/pressure/temperature of the ambient gas into which the spray is injected. The more engine-like the merit function can be defined, the more useful it is likely to be. The reviewer commented that it would have been nice to see the shift toward the more updated hardware happen earlier.

Reviewer 3:

The reviewer asserted that it would be nice to have seen fuel-air vapor contours, or some other model-experimental indicator of the mixture preparation quality degree. Ultimately, especially for cold start, this is the great challenge with minimal liquid impingement.

Reviewer 4:

The reviewer remarked that each of the individual tasks is well planned and executed. The quality of the experimental data is high, it is good to see the team has obtained more modern injectors in response to last year's comments, and progress in the simulations is good. In particular, the reviewer noted that the development of a merit function will be very helpful not just to these activities but to PACE overall. The individual tasks, however, do not seem as integrated as they could be. Simulations are being compared to data from outside the collaboration, some of which have pretty old data. Finally, it was not clear to the reviewer how the Nek5000 development is using results from the rest of the activities; many of the models are older, more standard models.

Reviewer 5:

The reviewer recognized this project is still in the beginning stage and more results will be available next year. With this note in mind, there was minimal reference toward one goal of this project—ensuring good mixture preparation near the spark source at spark timing. Possibly more focus on this goal will occur this coming year. Also, there is quite a focus on multi-dimensional modeling including Reynolds-average Navier-Stokes (RANS) and LES comparisons, which do not agree so well near the injector tip. Given the challenges in this multi-dimensional domain, the reviewer wanted to know if the team has or will, consider zero dimensional (0-D) or 1-D modeling strategies for spray penetration and evaporation rates. Having a physics-based correlation could be helpful for future reference including boundary conditions expanded beyond the six points chosen for this effort.

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:

Technical progress has been quite substantial for this project, according to the reviewer. Each of the aspects of this project, from different labs, consists of both experiment and simulation, and progress toward the goals has been steady and consistent. The development of the 3-D LVF technique is key to quantifying future coordinated work and quantifying the understanding of these sprays for future combustion system development.

Reviewer 2:

Even though the project is in Year 2 of 4, the reviewer was hoping to see connections to the three major outcomes on Slide 3. There was very little mention of how this work specifically leads to improved knock tolerance, lean-dilute combustion (especially challenging during cold start), and emissions reduction. The reviewer asserted that the bridge from the current work to the final objectives should be made more explicit.

Further, the reviewer wanted to know if it might be possible to include a new metric or merit function, which evaluates either the model or experimental results to the resulting mixture preparation (and lack of liquid impingement).

Reviewer 3:

The reviewer said the project was able to pivot its efforts and make up for lack of experimental access were noteworthy. Moving to the modernized injection hardware as early as possible will help the project overall.

Reviewer 4:

Each of the individual tasks has made significant progress in the past year, and the reviewer stated that there are some key outcomes of the work that will have a high impact. These four, in particular, will likely have a high impact:

- First, the inclusion of new injectors into the project.
- Second, the LVF measurements at elevated pressures and temperatures. This development will be very useful for better understanding and model validation at realistic conditions, whereas this was very difficult with the X-ray techniques that had to be run at less realistic conditions. The reviewer suggested that it would be helpful to identify what role the X-ray measurements will have now that this capability is online at SNL.
- Third, the inclusion of nozzle geometry in the RANS simulation. This is a dramatic improvement in results and is a high-impact outcome that can be incorporated immediately in industrial-standard work to improve prediction. The reviewer opined that it would be good to see the team publish this somewhere like the Society of Automotive Engineers (SAE) with broad industry reach.
- Finally, development of the merit function. This is an important step toward synthesizing all the knowledge from the project. As mentioned in the AMR presentation, the reviewer stated that it would be nice to connect this merit function, which is spray-centric, with some of the larger system-level considerations.

Reviewer 5:

said it appeared to the reviewer that COVID-19 did impact some of the X-ray work at a minimum. It would be nice to have seen more LVF measurements at more operating conditions and possibly such measurements are in the background or will be undertaken this current year.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration and coordination among team members seemed to be outstanding to the reviewer. The experiments and the simulations mesh well together and feed the input-output needs of each aspect. The results from each sub-project feed into the input of other sub-projects, leading to a high level of coordination and cooperation among team members.

Reviewer 2:

From the three spray talks, the collaboration appeared to be excellent to the reviewer.

Reviewer 3:

The reviewer found the spray team to be extremely well organized. The close coupling and coordination of efforts from ANL, ORNL, and SNL are commendable. The team also receives input from the AEC Memorandum of Understanding (MOU) and the Engine Combustion Network (ECN).

Reviewer 4:

As indicated in previous comments about the project structure, the reviewer said that there could be better coordination between the elements of the program, especially since there are simultaneously nice experiments and simulations being run. In particular, the Nek5000 development does not seem to be pulling much knowledge from the other pieces of the program. The reviewer stated each of the individual tracks is doing good things and all working toward the same goals, but it would be good for the team to establish tighter coordination when the new injectors come online.

Reviewer 5:

The reviewer recognized that the project solely includes national laboratories while collaborating with other partners, such as Industry participants and, in cursory fashion, universities. It would be nice to see more university involvement for augmenting measurements and analysis and, in addition, to grow the next generation of researchers.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said chasing a merit function is a laudable goal; however, it will be challenging to draw the line between what is "spray" versus what is "engine." However, it is only in reference to the influence upon engine combustion that the spray information has value. The selection of merit function parameters will be crucial to the future rationale for continuing this work. The move toward updated hardware is overdue and very welcome.

Reviewer 2:

The reviewer suggested that the project team please continue to be mindful of how this work can ultimately improve understanding as well as the practical challenges of cold-start mixture preparation and emission mechanisms (and knock control).

Reviewer 3:

The reviewer said obtaining shot-to-shot data sets will be very important, as well as multi-component fuels. Both are on the planned list.

Reviewer 4:

The future research is a continuation of the current work, and all the planned tasks are reasonable. It was unclear to the reviewer what the timeline is for these tasks. Based on the descriptions, it looks like this all might wrap up relatively soon. If so, it would be helpful to identify "success criteria" for the overall program and how it will be integrated into the greater PACE effort as well as industry practice. In particular, the merit function might be a good vehicle for that integration.

Reviewer 5:

The reviewer opined that one area that could use potentially more attention is consideration of simplified physics-based modeling strategies for spray penetration and evaporation rate, as previously noted above. Such a model could be very useful moving forward toward addressing boundary conditions beyond this current study.

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

Reviewer 1:

According to the reviewer, one of DOE's stated overall objectives is to better understand gasoline direct injection (GDI) sprays to support future high technology SI engines. This project fits very well into that category.

Reviewer 2:

The reviewer stated cold-start GDI challenge is great and is what keeps gasoline SI engines from being nearly zero emissions (not including CO_2). It is agreed that a fundamental knowledge base is first required, and this fact is important. Hopefully, from this knowledge base, creative technical solutions can be discerned.

Reviewer 3:

The reviewer said clarifying the fundamental understand of these spray processes will enable improvement to GDI engine concepts, enhancing energy efficiency and reducing emissions for the majority of on-road vehicles.

Reviewer 4:

The components of the project all meet the goals of the PACE program, and hence DOE objectives. The reviewer found that there is good transferability to industry, particularly through the RANS developments, and the diagnostics that are being developed at SNL could be used to meet DOE objectives on this program and others.

Reviewer 5:

The reviewer commented that the project supports DOE goals for ICEs. Its focus should lead toward better understanding of improving spray formation control for possibly operating more dilute, better controlling emissions under cold conditions, and possibly improving ITE.

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

Reviewer 1:

The reviewer stated that resources are excellent and appear to be fine.

Reviewer 2:

Resources for the team to achieve future milestones and objectives appeared to be sufficient to the reviewer.

Reviewer 3:

The reviewer stated resources are sufficient and the project is on schedule.

Reviewer 4:

Provided the upgraded injector hardware can be procured economically, the reviewer commented that the team appears to have the required resources.

Reviewer 5:

No comment was indicated by this reviewer.

Presentation Number: ace144
Presentation Title: Spray Wall Interactions
Principal Investigator: Lyle Pickett (Sandia National Laboratories)

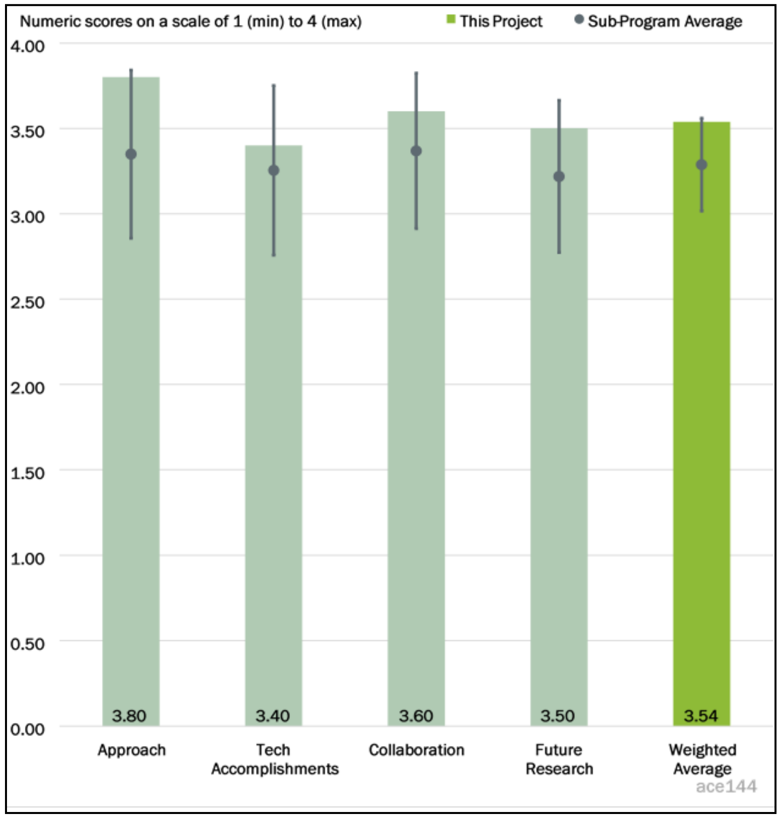

Figure 1-24 - Presentation Number: ace144 Presentation Title: Spray Wall Interactions Principal Investigator: Lyle Pickett (Sandia National Laboratories)

Presenter

Lyle Pickett, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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:

ACE144 seemed to the reviewer to have all the right elements to an outstanding approach by linking to the PACE Consortium goals and having multi-lab coordination in experimental and computational endeavors. The approach to break down the very complicated spray-wall interaction (SWI) physics is the clearest path forward. Additionally, the reviewer asserted that the use of unique capabilities from the labs (neutron imaging, high-fidelity simulations, HPC, etc.) is also outstanding.

Reviewer 2:

The reviewer praised the project as outstanding as the scientific study of cold engine in-cylinder liquid films is incredibly challenging. The fundamental approach currently being applied is excellent.

Reviewer 3:

The reviewer commented that the project uses established and novel techniques to investigate the important SWI and is a well-designed project.

Reviewer 4:

The reviewer found this to be a very useful approach to use multiple experimental pathways to gain insight into physical behaviors to compare to simulation results.

Reviewer 5:

According to the reviewer, the project's work does very well to address the major technical barriers and understand the complex spray-wall interactions that can occur in engines. A minor suggestion would be to somehow use dimensional analysis or scaling analysis to establish applicability of the results to a broader spectrum of engine conditions and fuels. For example, the reviewer inquired as to whether the models being developing could ultimately be used for diesel engines.

The reviewer suggested that the work by Ketterer at the Massachusetts Institute of Technology (MIT) roughly 5-10 years ago seems like it may be relevant to this work. If the PIs are not familiar with this work, it may be worthwhile to examine it.

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 accomplishments by the project teams were very impressive to the reviewer, and moreover the team did very well to adapt and prepare in light of COVID-19-related impacts. The insights into double injections were particularly interesting for this reviewer.

Reviewer 2:

The reviewer found that the project's progress is excellent and tasks were completed as expected.

Reviewer 3:

According to the reviewer, the project made very relevant progress in identifying shortcomings in simulation predictions that should lead to improved spray behavior models.

Reviewer 4:

The reviewer stated that the accomplishments and progress are good. Even though the project is in Year 2 of 4, the reviewer was hoping to see more connections to the three major outcomes on Slide 3. There was very little mention of how this work-in-progress leads to improved lean-dilute combustion (especially challenging during and after cold start) and emissions reduction. The reviewer suggested that the bridge from the current work to the final objectives should be made more explicit.

Reviewer 5:

The reviewer noted that the project is complex and large with many areas which achieved progress. The fact that six of the seven milestones were completed or are on track is evidence of this progress and technical accomplishment. The reviewer said new experimental spray chamber upgrades at ORNL, ANL, and SNL show good progress as does ANLs completed splashing criterion SWI model implemented in a UDF. The additional diagnostics progress to quantify and speciate films is also encouraging.

The reviewer did not completely understand the OEM view of the importance of more understanding or better simulation of SWI during cold start. The reviewer asked if this increased effort was foreseen to still be needed within the PACE program, given future emissions regulations and the strong shift toward electrification. Does hybridization of ICEs make cold start more important with more frequent engine starts-stops?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

From the three spray talks, the collaboration appeared to be excellent to the reviewer.

Reviewer 2:

The reviewer commented many entities involved in the project collaborated well toward the project goal.

Reviewer 3:

The reviewer remarked that the PACE program has provided a great framework for collaborations between labs and facilities.

Reviewer 4:

As stated before, the clear multi-lab coordination was evident to the reviewer, and the alignment to PACE seems to be driving the right focus of the teams.

Reviewer 5:

According to the reviewer, the projects are well coordinated with each other. It would be good to try to involve industry a bit more beyond the ECN, even if it were only in an advisory fashion.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

Future research was logical to the reviewer.

Reviewer 2:

According to the reviewer, increased fuel pressure studies are of interest to industry.

Reviewer 3:

The proposed research is sound and logical. The reviewer thought that it will be particularly important to focus on a wide range of wall temperature conditions in the future as spray-wall interactions can be very non-linear as wall temperature varies (e.g, see the Leidenfrost effect).

Reviewer 4:

The reviewer asserted that the proposed future work is outstanding, and the proposed modeling and experimental efforts appear to be very appropriate. However, the reviewer's only concern is that many GDI engines use side-mounted injectors. Perhaps the continuous (upward airflow) experiments will provide insights into the effect of gravity on vertical fuel films (not sure if this is important over the time scale of cold-start engine cycles; however, cold engine oil dilution by fuel can and does occur). Also, the reviewer asked if the project team has any thoughts on the second cold-start cycle.

Reviewer 5:

The reviewer said the future research proposed is clear and seems like the natural extension of the in-flight work. Specifically, the execution of the SWI experiments, film thickness quantification, experiments with the new GDI injector, and trying to match the simulations to the new data should move toward the PACE goal of being able to understand and accurately simulate cold-start engine physics and emissions. Maybe it is detailed within the PACE workflows, but there must be other downstream work to go from an accurate simulation prediction of SWI and the subsequent combustion and engine emissions. The reviewer asked the project team for help in orienting the reviewers as to the relative importance of the SWI understanding and modeling deficiency toward this PACE goal of minimizing tailpipe emissions and cold-start simulation. The reviewer wanted to know whether SWI is less or more important than kinetics, thermal boundary conditions, in-cylinder flows, and combustion.

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

Reviewer 1:

The reviewer said the project ultimately aims to develop tools to help reduce emissions from engines, and thus it supports DOE objectives.

Reviewer 2:

The reviewer affirmed that, yes, this project's support is aligned to the PACE program and the goal of enabling fuel-efficient, clean, cost-effective ICEs.

Reviewer 3:

The reviewer said cold-start GDI challenge is great and is what keeps gasoline SI engines from being nearly zero emissions (not including CO_2). It is agreed that a fundamental knowledge base is first required, and this fact is important. Hopefully, from this knowledge base, creative technical solutions can be discerned. While not directly related to this specific project, the reviewer encouraged an awareness and possible consideration of alternatives. For example, a number of newer engines were seen applying both PFI and GDI together to improve cold-start mixture preparation as well as high-load engine knock.

Reviewer 4:

According to the reviewer, an understanding the spray-wall interaction is a necessary step in designing more efficient engines with lower emissions.

Reviewer 5:

Fuel spray simulation is a fundamental building block for engine combustion simulations and must be improved in order to design better engines. The reviewer noted that improved models will help engineers make engines more efficient.

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 are adequate for completing the planned tasks within the planned timeframe.

Reviewer 2:

Resources appeared to be fine to the reviewer.

Reviewer 3:

Resources seemed sufficient to the reviewer for this project.

Reviewer 4:

The reviewer said the project is doing critical work that should be accelerated with additional resources.

Reviewer 5:

The reviewer commented that laboratories, computational resources, and staff seem appropriate, and the pacing item seemed to be delays from COVID-19 restrictions.

Presentation Number: ace145
Presentation Title: Cold Start Modeling and Experiments for Emissions Reduction
Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

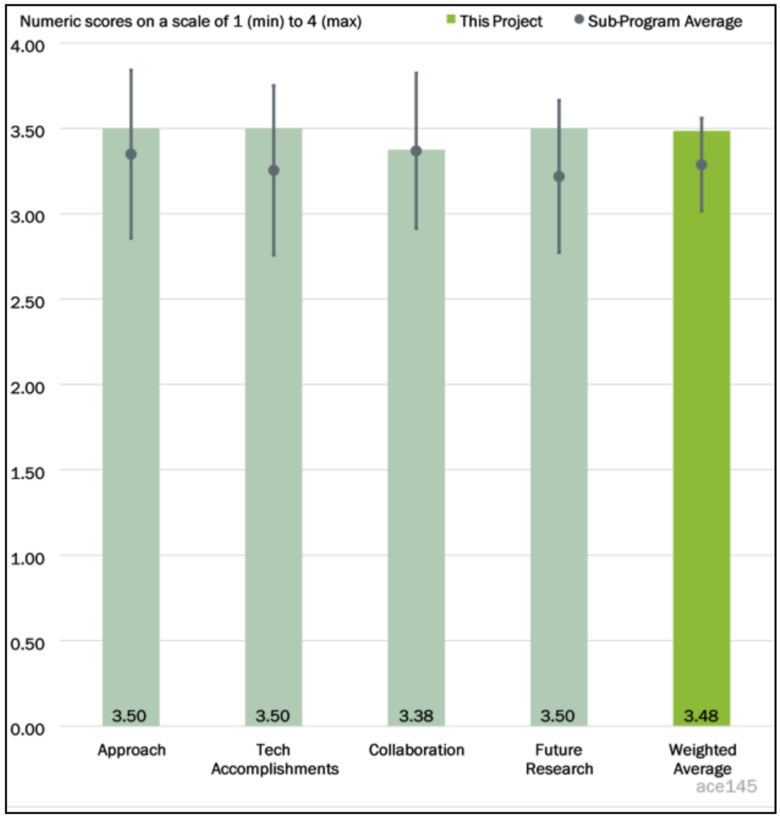

Figure 1-25 - Presentation Number: ace145 Presentation Title: Cold Start Modeling and Experiments for Emissions Reduction Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

Presenter

K. Dean Edwards, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 suggested that, for the cold-start data, the team should consider using the fuel mass (or airflow if A/F mixture remains constant) as the control variable. Spark location, exhaust temperature, emissions all become responses. It is fuel flow that correlates most closely with exhaust temperatures and thus catalyst heating rate, which makes it the best independent variable. Stating that retarding the exhaust cam improves heat flux, while true, is only because more fuel is being injected. It would be far more insightful, the reviewer opined, to be able to say that at a given injected fuel mass, the chosen approach (injection timing, cam settings, and engine speed) improved emissions, exhaust temperature, or engine stability. Spark location can be used as an indication of burn rate. The reviewer said methods that achieve faster burn rates will have more retarded spark and vice versa.

The reviewer asserted that the neutronic engine is wild. Getting thermal boundary conditions for the engine start conditions is an important step and worth the effort.

Reviewer 2:

The reviewer stated that this project is focused on modeling and experiments to improve emissions from cold start. The highly-collaborative approach leverages expertise across multiple labs and teams. The reviewer further described the project as well designed, feasible, and very important during the move toward cleaner engines.

Reviewer 3:

The reviewer believed that it is a very well-designed approach to obtain solid validation data in the fired engine cylinder to benchmark models. However, presentation of the approach is confusing and needs to be better laid out. The reviewer acknowledged these types of data are highly valuable and difficult to obtain. The neutronic engine is a solid approach for performing measurement of large-scale object, like an engine.

Reviewer 4:

According to the reviewer, this is an extremely good project that ties neutronic engine measurements, multi-cylinder engine testing and simulations for quantifying/measuring and modeling/simulating cold-start emissions, which are critical. The question that needs to be answered is how relevant and useful the measurements from the neutronic engine will be for "real-world" conditions and how many measurements can be made since the beam is stationery and engine needs to be rotated. Coolants used are also differently. The reviewer suggested that a transfer function from these engine measurements to the multi-cylinder engine testing needs to be evaluated based on dimensional and scaling analysis or other methods for better validation and utility of the data.

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 great progress toward modeling of cold start.

Reviewer 2:

The reviewer remarked that the engine-out soot data are very interesting and useful.

Reviewer 3:

This reviewer explained that the project has met or is on track to meet all of its major milestones on both the hardware side (neutronic engine design, etc.); experimental side (validation data); and modeling side (identifying gaps and needs for cold-start modeling, spray modeling with flash boiling phenomena, CHT for improved boundary conditions, etc).

Reviewer 4:

According to the reviewer, the technical accomplishments and progress seem to be in line with the schedule. For the CFD results, mixture fraction evolution during cold start should be shown along with vapor penetration to understand the fundamental mechanisms of combustion and emissions formation, especially with multi-component vaporization being predicted. The reviewer wanted to know how the model predicts soot attributed to wall wetting and whether that can be matched with the experimental results. The team should also think whether some of these results could be translated for engines employing thermal barrier coatings and its impact on fuel efficiency and exhaust temperatures.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

As in all aspects of PACE, the reviewer found great collaboration.

Reviewer 2:

The reviewer said, though much of the work is spearheaded by ORNL, the complex chart with push pins shows how it is all tied together with other national laboratory work. OEM involvement will be important, and this work is critical for OEM engine development.

Reviewer 3:

Although this specific project is under ORNL, the reviewer stated that it is part of the overall PACE project that includes all of the national laboratories, OEMs, and software vendors. For the cold start modeling efforts, researchers from ORNL, LLNL, SNL, and ANL are all bringing their expertise to help attack this difficult problem.

Reviewer 4:

There are some collaborations and interactions between labs, but it was not entirely clear to the reviewer how they connected. A better presentation of the story and between teams will 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. Note: if the project has ended, please state project ended.

Reviewer 1:

This reviewer observed clear and relevant future research, including modeling efforts (both performing simulations and implementing improved models) and a transition to the PACE common engine.

Reviewer 2:

The reviewer was looking forward to the MCE EcoBoost™ installation.

Reviewer 3:

The reviewer asserted that the proposed next steps are critical for accomplishing the goals of this project, especially the CHT runs. CFD modeling of soot will be critical to knowing the limitation of existing soot models.

Reviewer 4:

According to the reviewer, the proposed work is solid but needs to better coordinated between teams and labs.

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

Reviewer 1:

PACE goals directly support OEM goals of improving efficiency and emissions. When successful, the reviewer indicated that commercialization is likely.

Reviewer 2:

According to the reviewer, the cold-start effort is highly relevant, and it is very important to address the major emission issue and some design challenges.

Reviewer 3:

The reviewer opined that the project is doing very important work at accurately quantifying cold-start performance and emissions; this level of detail has not been done before.

Reviewer 4:

The reviewer asserted that this project supports the overall DOE objective of more efficient and cleaner engines. Cold start is the primary source for criteria pollutants for modern engines; so, this is a key area to work on.

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

Reviewer 1:

This reviewer believed that resources are sufficient if maintained at the current level.

Reviewer 2:

The reviewer said the resources are deemed sufficient for this work.

Reviewer 3:

The reviewer stated the resources are reasonable and encourages better coordination with other labs.

Reviewer 4:

This reviewer described resources as sufficient.

Presentation Number: ace146
Presentation Title: Direct Numerical Simulation (DNS) and High-Fidelity Large Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes
Principal Investigator: Muhsin Ameen (Argonne National Laboratory)

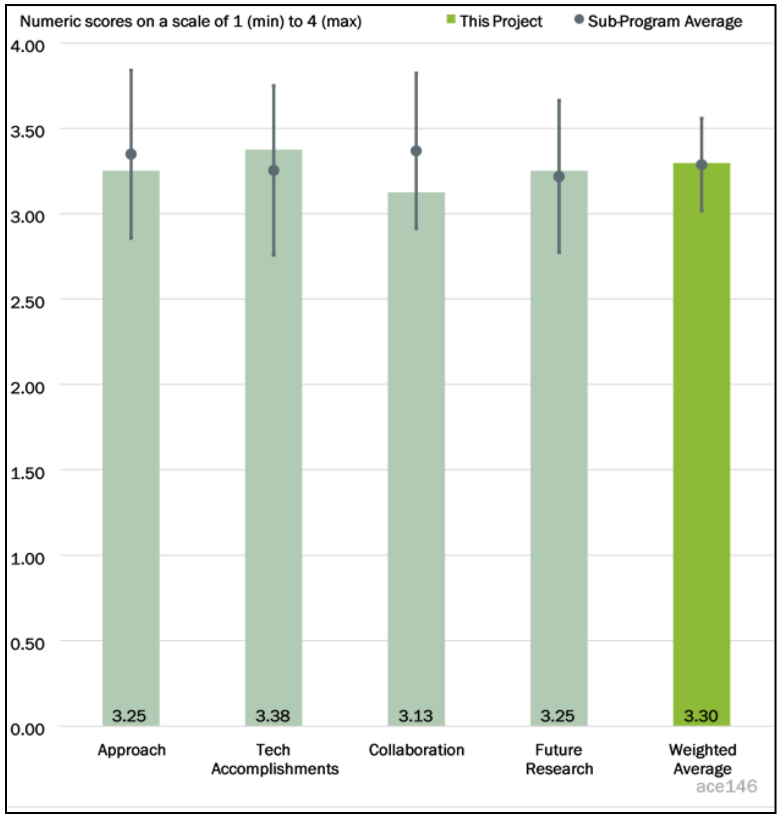

Figure 1-26 - Presentation Number: ace146 Presentation Title: Direct Numerical Simulation (DNS) and High-Fidelity Large Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes Principal Investigator: Muhsin Ameen (Argonne National Laboratory)

Presenter

Muhsin Ameen, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 approach of using and developing high-fidelity codes Nek5000 from ANL and S3D from SNL for accurate simulation of SI engine flow and combustion seemed fine to the reviewer.

Reviewer 2:

The reviewer noted that the project uses high-fidelity simulation tools and DOE leadership-class machines to develop accurate sub-models to improve understanding of in-cylinder combustion, knock, flame-wall interaction, heat transfer, and cycle-to-cycle variation.

Reviewer 3:

The approach looked valid to the reviewer, but it is not very clear what benefit Nek5000 is supposed to bring. Nek5000 is not an affordable solution for automotive industry.

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 remarked that the project made significant progress in demonstrating the need for high-fidelity simulations to capture cycle-to-cycle variation (CCV), using high-fidelity simulations to provide insights on wall boundary layers and turbulent kinetic energy distribution, DNS on motored engine flows with experimental validation and improved high-temperature models, and two-dimensional (2-D) DNS of knock and detonation under boosted GDI engine conditions.

Reviewer 2:

The reviewer said it was a good idea to couple an engineering LES solution of open-cycle from the commercial CFD code CONVERGE with a high-fidelity LES solution of closed-cycle from Nek5000. However, the impact of the initial flow field from the engineering LES solution on further development during the compression stroke needs more study.

The reviewer noted that the project team solved DNS of compression/expansion motoring strokes on a transparent combustion chamber (TCC-III) engine at 500 revolutions per minute (rpm) and validated flow field and heat flux at a position on the cylinder head, which showed a reasonable match with the experiment.

The reviewer commented that spray sub-models and the ECFM combustion are implemented in Nek5000 and verified if the models work properly.

Reviewer 3:

Given the goals and the approach, the accomplishment is solid, but the positioning and usage of Nek5000 was unclear to the reviewer. The reviewer wanted to know what the primary use of Nek5000 is where there are DNS, LES (engineering level) and RANS and whether these tools provide a clear benefit to the industry.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found excellent collaboration across the project teams, as well as with external collaborators.

Reviewer 2:

The reviewer stated that overall, collaboration with PACE project teams and various external organizations seem good, but was somehow limited to all Nek5000-related.

Reviewer 3:

The DNS and the high-fidelity LES did make good accomplishments; however, it was not clear to the reviewer how they are leveraging each other. Slide 21 mentions that high-quality simulation data sets will be used to develop improved sub-models. A comprehensive plan is needed.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the future work is well planned to address barriers to better understand the dynamics of A/F mixture preparation and stochastic combustion problems, such as CCV, misfire, and knock.

Reviewer 2:

All the proposed future work looked reasonable to the reviewer as it focuses on spray and combustion model implementation in Nek5000.

The reviewer opined that a very long simulation time and difficulties in meshing a real engine geometry with intake and exhaust manifolds and swirl or tumble control valves will make Nek5000 very difficult to make a tool for future handling of open-cycle flow simulation.

Reviewer 3:

The list of proposed research items looked reasonable to the reviewer, but the Nek5000 work seems to be a continuation of model implementation. The reviewer was afraid that, given the model development pace, it may be a little hard to keep it up with the paradigm shift (electrification).

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

Reviewer 1:

The reviewer said the project is relevant to and supports DOE objectives by developing a better predictive tool for engine development further optimized for highly transient and unstable operating conditions.

Reviewer 2:

The reviewer commented that the project supports PACE in developing accurate sub-models for in-cylinder flow, combustion, heat transfer, and combustion stability.

Reviewer 3:

The reviewer noted that the project is aligned in support of overall DOE objectives for clean and efficient transportation.

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

Reviewer 1:

This reviewer commented that computer resources seemed insufficient.

Reviewer 2:

It appeared to the reviewer that the project has sufficient resources.

Reviewer 3:

The reviewer said the project has sufficient resources to achieve the stated milestones in a timely fashion.

Presentation Number: ace147
Presentation Title: Mitigation of Abnormal Combustion
Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

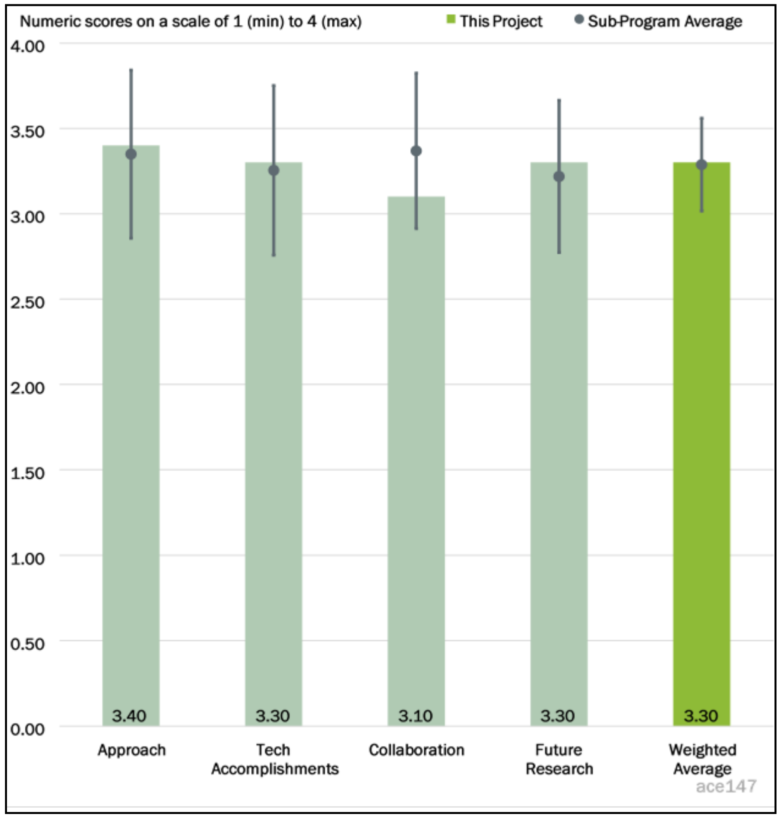

Figure 1-27 - Presentation Number: ace147 Presentation Title: Mitigation of Abnormal Combustion Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Presenter

Derek Splitter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 three tasks that were reviewed are more or less unrelated: each task individually is well approached and planned to address key technical barriers and understand the fundamentals of the problems being examined.

For the stochastic pre-ignition (SPI) task, a comment is that the nitric oxide (NO)/nitrogen dioxide (NO_2) hypothesis is very interesting and could explain the commonly observed trend that SPI is more likely under slightly lean conditions (where oxides of nitrogen [NO_x] levels tend to be slightly higher). This is outstanding work by the project team to develop and plan to test that hypothesis.

Reviewer 2:

The reviewer stated that this is a creative approach to investigation of the notoriously difficult topic of pre-ignition.

Reviewer 3:

This reviewer remarked that technical barriers are addressed for the project, which is well-designed and feasible.

Reviewer 4:

According to the reviewer, low-speed pre-ignition (LSPI) is an ongoing challenge for industry. This work provides insight into processes leading to LSPI that continue to be important. The approach of focusing on fuel-oil interaction is appropriate, although over-reliance on a technique that measures bulk oil dilution could be misleading, as dynamics in the ring-pack could differ from what is seen as the oil returns to the reservoir.

The application of machine learning (ML) or other predictive models to combustion systems, such as abnormal combustion in spark-ignition (SI) engines, is a worthwhile research endeavor that has a low probability of success, but a high payoff if successful. The reviewer said that the approaches described herein are sound and appropriate but should also make use of learnings from previous efforts in this area from combustion researchers outside of the DOE laboratories.

Reviewer 5:

The reviewer remarked that this report details an ongoing research project in combustion abnormalities including stochastic pre-ignition.

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 called the accomplishments of all three tasks impressive and stated that each of the individual projects has done an excellent job of explaining the observations the project team has made.

Reviewer 2:

This project continues to show good progress, according to the reviewer.

Reviewer 3:

The reviewer reported that this project is on track to meet all milestones for FY 2021, including tasks on the impact of spray wall wetting on LSPI, knock mitigation through EGR, and applying machine learning to evaluate the dynamics of abnormal combustion.

Reviewer 4:

The reviewer commented that Task O.E.09.01 continues to demonstrate progress in isolating and quantifying mechanisms, such as fuel impingement that may lead to LSPI.

Task O.E.08 demonstrates strong initial progress toward developing the datasets needed to train models for abnormal combustion prediction, as well as the ability to detect pre-ignition prior to the occurrence of "super-knock." This progress sets the stage for the next stage of the project, where this information will be leveraged to attempt to inhibit the process, once detected.

Task O.E.02 accomplishments focused on the installation of a new experimental apparatus, but the reviewer noted that the project team was unable to demonstrate results in time for the Annual Merit Review (AMR).

Reviewer 5:

There are some interesting results and root cause speculation from the fuel impingement study, and the reviewer looked forward to NO/NO_2 experiments. The reviewer stated that the claim of "ML Approach Shows Promise for Knock Prediction" is not well substantiated with results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that specific collaborations exist both between the tasks within PACE and with industry partners. This helps both PACE objectives of scientific advancement and transfer of knowledge to industry.

Reviewer 2:

This project is part of the PACE program, which the reviewer indicated is a collaborative effort across multiple national laboratories. There is also significant collaboration with industry (Lubrizol and GM).

Reviewer 3:

The reviewer reiterated that the three tasks and projects are distinct. The collaboration and coordination of the projects with the overall Partnership to Advance Combustion Engines (PACE) effort appears to be very good. It would be helpful to have some industry engagement on the machine learning effort in the future, even if only in an advisory fashion.

Reviewer 4:

The reviewer stated that this project is predominantly Oak Ridge National Laboratory (ORNL) only.

Reviewer 5:

The reviewer suggested that simulation for the SPI project should be expanded to investigate some of the chemistry ideas in support of the experiments.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented that the proposed future research across all tasks is appropriate and very much in line with the overall goals of the tasks and the PACE program.

Reviewer 2:

The reviewer said that the proposed future work is a progression of the previous work. The addition of the next-cycle control is a useful adjunct.

Reviewer 3:

Future work was described by this reviewer as well-thought-out and presented. Challenges and barriers are also addressed and documented.

Reviewer 4:

According to the reviewer, all of the proposed future work is sound and logical. For the SPI effort, it might be good to include in the future work an explicit comparison and/or evaluation of the fuel-in-oil from the diagnostic method being used to other methods. This seemed to be implied as being part of the work, but an explicit focus on it might be helpful.

Reviewer 5:

Fuel-spray wall wetting may be a contributor to SPI, but the reviewer remarked that it may not be the only root cause. There is a need to expand the scope of this project to investigate other potential root causes.

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

Reviewer 1:

The reviewer indicated that improving SI engine efficiency by allowing engines to operate closer to the knock margin is a very useful objective.

Reviewer 2:

The reviewer commented that abnormal combustion (mainly knock and LSPI) is a barrier toward increased efficiency in SI engines. A project that addresses this definitely supports the overall DOE objectives.

Reviewer 3:

The reviewer noted that all three efforts aim to enable more efficient engines and thus are in support of U.S. Department of Energy's (DOE) objectives.

Reviewer 4:

According to the reviewer, pre-ignition can limit engine efficiency at some conditions so understanding it better will help engineers design better engines that are more efficient.

Reviewer 5:

The reviewer commented that the tasks reviewed here all directly support DOE's goals of supporting the continued development of next-generation, high-efficiency internal combustion engines that will lead to improved vehicle fuel economy and reduced emissions.

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

Reviewer 1:

This reviewer believed that resources are sufficient, as long as funding is not reduced going forward.

Reviewer 2:

The reviewer said that ORNL is performing most of the work and the budget seems appropriate.

Reviewer 3:

The reviewer noted that the project teams all have adequate resources for reaching the stated goals in their respective timeframes.

Reviewer 4:

The reviewer found that resources for the projects are sufficient to continue to make progress commensurate with the goals and PACE timelines.

Reviewer 5:

According to the reviewer, resources should increase for the SPI project so that researchers can finally determine a root cause for the phenomenon.

Presentation Number: ace153
Presentation Title: Chemistry of Cold-Start Emissions and Impact of Emissions Control
Principal Investigator: Melanie Moses-DeBusk (Oak Ridge National Laboratory)

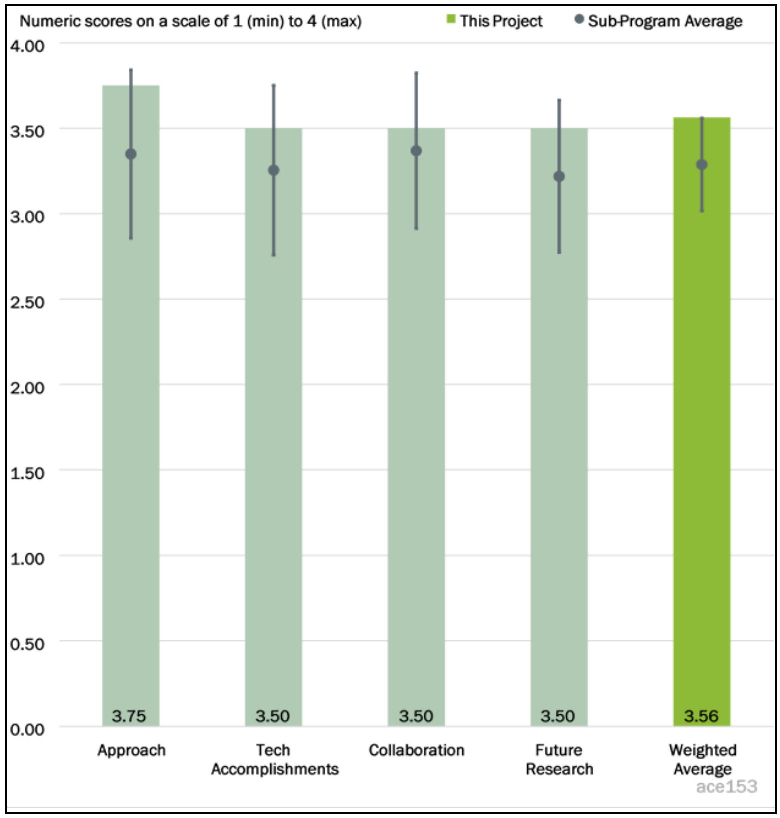

Figure 1-28 - Presentation Number: ace153 Presentation Title: Chemistry of Cold-Start Emissions and Impact of Emissions Control Principal Investigator: Melanie Moses-DeBusk (Oak Ridge National Laboratory)

Presenter

Melanie Moses-DeBusk, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 believed that the progress on this project has been excellent and has been very well designed and especially looked forward to the data on hybridized vehicles.

Reviewer 2:

The proposed approach is appropriate as hydrocarbon (HC) traps are a potential emissions control solution option for reducing cold-start hydrocarbon emissions. The reviewer noted that the project targets speciation of cold-start HC emissions from consumer, on-road vehicles. Specifically, vehicle platform (model year [MY] 2018 gasoline direct injection [GD] pickups) and chassis dynamometer test cycles (cold start [CS] and New York City Cycle [NYCC]) represent a relevant and challenging test environment.

Reviewer 3:

This is a thorough on-vehicle speciation work for HC traps. This should foster future HC trap development and optimization.

Reviewer 4:

There was a good choice of high-volume vehicles with significant challenges to achieve lower tailpipe emissions, according to the reviewer, who suggested that it would be beneficial to include both the Federal

Test Procedure (FTP) and the low speed NYCC to probe the feasibility of the technology in real world applications. It would be helpful to explore more realistic aging temperatures (700°Celsius [C] is very mild even for underfloor location or hybrid 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 said that this project is on schedule and passes all of its necessary performance indicators. The dissemination of information through manuscripts, presentations, and databases will be important for the field.

Reviewer 2:

The review noted that there was excellent progress, especially with the HC speciation data. The challenge is how to best utilize the large amount of data to help develop a better HC trap and/or a better mathematical model.

Reviewer 3:

The reviewer observed good technical accomplishments in terms of understanding the effectiveness of HC traps and the addition of gasoline particulate filter (GPF) on the -cold-start emissions (especially on bag 1 and first 250 seconds of it). The reviewer also noted use of Fourier-transform infrared spectroscopy (FTIR) analysis methods to characterize the impact of the same aftertreatment combinations (compared to the three-way catalyst baseline) on non-methane (NM) paraffins, particulate matter and particle number.

Reviewer 4:

According to the reviewer, overall progress appears to be going well, with all milestones met or on target.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration is well organized as it includes informal technical advisors from Ford (original equipment manufacturer [OEM]) and Umicore (supplier) as well as participation in Crosscut Lean Exhaust Emissions Reduction Simulations (CLEERS) (sharing results with national laboratory researchers). Umicore also provides HC traps and gasoline particulate filters (source of new and used filters).

Reviewer 2:

The team is quite strong, with ORNL, Umicore, and Ford—a national laboratory, coater, and OEM—as well as the CLEERS and U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) communities.

Reviewer 3:

There appears to be strong collaboration between ORNL, Umicore, and Ford.

Reviewer 4:

The reviewer stated that the project team is excellent, with complimentary capabilities and skillsets (national laboratory, suppliers, OEM). It will be good to show the generated HC speciation results that could lead to better HC trap design; ultimately, catalyst suppliers need to further develop the HC trap technology for improved performance and durability. The reviewer suggested that collaboration with a modeling team could also be beneficial.

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

Reviewer 1:

While all milestones except submitting a manuscript have been met for this 3-year project (Fiscal Year [FY] 2021 is the last year), the reviewed opined that the proposed future work, while very relevant, is likely outside of the current scope (unclear from the Remaining Barriers and Future Work slide).

Reviewer 2:

The reviewer stated that there was a good plan to evaluate the HC performance under the low-speed NYCC and it will be beneficial to add another aging temperature if possible (800℃ or 900℃). It will also be helpful to put various HC species into three different buckets—not absorbed, absorbed and released, and absorbed and converted. This exercise may help HC catalyst design, and it may have implications on future fuel specifications to achieve near-zero emissions.

Reviewer 3:

As stated above, the reviewer was highly looking forward to data on hybridized vehicles. Stop-and-go data would also be incredibly useful.

Reviewer 4:

The reviewer stated that the future work looks interesting with expansion into stop-and-go and hybrid applications.

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

Reviewer 1:

Per the U.S. DRIVE Advanced Combustion and Emission Control technical team roadmap, HC traps are important for controlling cold-start emissions from high efficiency engines to allow them to achieve the U.S. Environmental Protection Agency (EPA) Tier 3 Bin 30 target. The reviewer commented that enablement of high efficiency engines directly contributes to reduction of imported petroleum use and carbon emissions.

Reviewer 2:

According to the reviewer, this project directly meets DOE objectives by providing fundamental understanding of speciation and targeted emissions reductions.

Reviewer 3:

The reviewer said that this project supports the overall DOE objectives by enabling technology development to reduce cold start emissions to meet stringent future regulations.

Reviewer 4:

The reviewer found that this project helps to reduce tailpipe emissions to improve air quality and address global climate change.

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

Reviewer 1:

The reviewer believed that the project has sufficient funding, especially since it should be coming to a close soon.

Reviewer 2:

According to the reviewer, this is a relatively well funded project at almost $500,000 per year over 3 years through a DOE VTO 2018 lab call.

Reviewer 3:

Sufficient resources were observed by this reviewer.

Reviewer 4:

Funding appeared to the reviewer to be sufficient. The team and facilities are well suited to the task.

Presentation Number: ace155
Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications
Principal Investigator: Qigui Wang (General Motors, LLC)

Presenter

Qigui Wang, General Motors, LLC

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

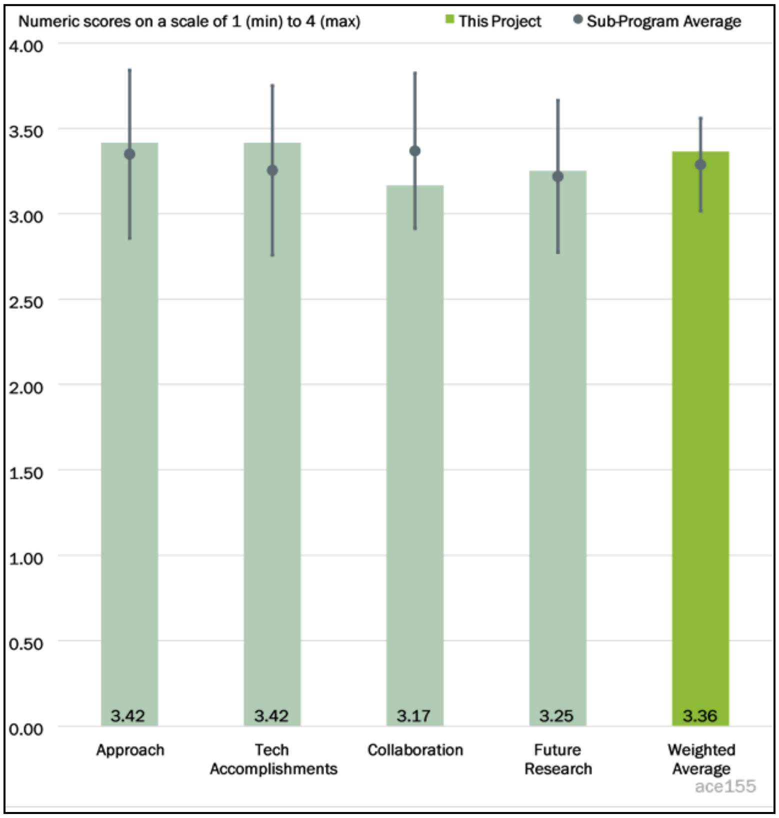

Figure 1-29 - Presentation Number: ace155 Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications Principal Investigator: Qigui Wang (General Motors, LLC)

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 performing the work to be fine. It looked like the program team made good progress over the last 12-15 months, despite all of the disruptions of 2020.

Reviewer 2:

The reviewer said that the approach was nicely laid out in a flow chart on Slide 4. The decision to start with two engine options (V8 and 6 L) was interesting to see and showed that, had the metrics for success been different (absolute gains versus relative gains), a different solution may have been chosen.

Reviewer 3:

The reviewer stated that the approach of this project— developing techniques to use advanced combustion, lightweight materials, and manufacturing techniques to expand engine operating efficiency and to enable lighter weight engines for better performance and fuel economy—is feasible. The project has already shown good progress using this approach.

Reviewer 4:

The reviewer commented that the project is well planned and, given that it is near the end, expected that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 5:

According to the reviewer, the mass reduction approach is good and targets key areas of weight reduction opportunities. Combustion development effort is interesting but not very different from previous programs from the organization.

Reviewer 6:

The reviewer really questioned the baseline for this project. A greater than 10% improvement in fuel economy compared to a 2015 engine seemed rather weak. Current Corporate Average Fuel Economy (CAFE) regulations require approximately 3.7% reductions every year, and this is already a 2015 engine so lots of improvements can be readily made. The reviewer suggested raising the goal to perhaps a 25% improvement.

The reviewer requested that the project team please include a cost assessment relative to baseline, especially since the team is choosing the V8 over the downsized engine based on cost effectiveness (Slide 9).

The reviewer did not see a major bottleneck that the team is trying to address. There seems to be a bunch of incremental improvements; while these are not trivial or easy, the reviewer asked if there were any element that is especially hard to achieve commercially. If so, that might be worth highlighting.

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 the work progress to be good for the past year, given the challenges of COVID-19.

Reviewer 2:

The reviewer asked why the project team chose the ultra-high pressure (P) injection at 1,000 bar and suggested also adding 600 and 800 bar to see if there is any significant improvement versus cost.

The reason for rejecting the 3.7L turbo engine was not quite clear to the reviewer. If cost effectiveness, it will be important to show the calculations to guide future projects.

Reviewer 3:

The approach taken to date seemed good to the reviewer, especially with the mid-point program gateway for the technology downselect leading into Phase II (Validation and Demonstration). The reviewer looked forward to seeing what the effective, net fuel consumption benefit will be when the technologies are combined in the engine.

Reviewer 4:

Although many accomplishments were highlighted, the reviewer commented that it was unfortunate that time did not allow for more depth of detail on these. The reviewer thanked the project team for including additional information on the technical accomplishments in the backup slides.

Reviewer 5:

The reviewer commented that the project has shown the potential of overcoming its stated barriers. Those barriers that need to be overcome in the upcoming year have clear pathways and approaches to allow for solutions.

Reviewer 6:

In the past few years, the reviewer has seen a decrease in evidence presented in these AMR reviews to confidently share that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found good coordination of partners.

Reviewer 2:

The collaboration seemed good to the reviewer. It may be a bit early to judge based on limited results.

Reviewer 3:

It seemed to the reviewer like most of the work done to date has been performed by GM. As the team moves into Phase II, the reviewer would expect to see the engagement from the project partners step up considerably, given their focus on materials and manufacturing methods.

Reviewer 4:

It was interesting to the reviewer to note that all of the outside collaborations were on the Lightweight Materials & Manufacturing Solutions part of the project. The reviewer asked if there were a reason that the Advanced Combustion Technologies part of the project did not have collaborators.

Reviewer 5:

The reviewer found the team put together by GM to be impressive. The only thing that can be seen as a detractor is that the advanced combustion research side of the project has only one contributor (GM). This leads to the question of why that area is less of a focus area than the light weighting. The team could have used members from ORNL, Argonne National Laboratory (ANL), or Sandia National Laboratories (SNL) as well as several universities, to aid in the advanced combustion area.

Reviewer 6:

There seems little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. The reviewer believed that there should be more effort on fleet and other engagements in these programs.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future research is outstanding, and the reviewer looked forward to seeing the team's progress next year.

Reviewer 2:

According to the reviewer, the plan going forward looks reasonable and thorough.

Reviewer 3:

The plan for completing the program looked sensible to the reviewer.

Reviewer 4:

The reviewer said there was a good plan.

Reviewer 5:

The reviewer stated that ongoing plans will be interesting to see.

Reviewer 6:

It seemed to the reviewer that there is relatively limited time— a year and a half— to complete the objectives, so it would be good to speed up (understanding that COVID-19 may have played a role). As mentioned previously, please include the impact of lower P injection to assess whether there is a diminishing return beyond 600 bar (which is commercialized).

Lots of work has already been done on dedicated exhaust gas recirculation (EGR). Please make sure that you address any real OEM concerns on barriers to commercialization.

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

Reviewer 1:

According to the reviewer, the project targets are good and in line with DOE objectives as they were stated at the start of the project.

Reviewer 2:

The reviewer observed that the project addresses fuel economy improvements, a very important task ahead for transportation.

Reviewer 3:

The reviewer found that this project supports overall DOE objectives of reducing fuel use within the United States to conserve energy resources and looks to be making good progress toward that goal.

Reviewer 4:

Objectives were to improve engine efficiency and simultaneously reduce engine weight. The reviewer opined that this project achieves both while reducing the fuel consumed and the associated greenhouse gases (GHG).

Reviewer 5:

The reviewer commented that light weighting and advanced combustion are two areas that can increase a vehicle's fuel efficiency. The advanced techniques proposed are complex enough that manufacturers may shy away from investigating them if DOE were not there to help fund the research. This project supports DOE's objectives.

Reviewer 6:

The reviewed responded that the project somewhat supported DOE objects because the reviewer believed that battery electric vehicles (BEVs) will begin to dominate medium-duty (MD) trucks in the next few years, bringing into question significant investments in engines.

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

Reviewer 1:

Resources seemed fine to the reviewer.

Reviewer 2:

Resources looked sufficient to the reviewer.

Reviewer 3:

The reviewer felt that the project was generously funded, but not overly so.

Reviewer 4:

This reviewer observed appropriate resources for the goals that were set and the achievements made.

Reviewer 5:

The resources appeared sufficient to this reviewer.

Reviewer 6:

This reviewer stated yes.

Presentation Number: ace156
Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development
Principal Investigator: Michael Shelby (Ford Motor Company)

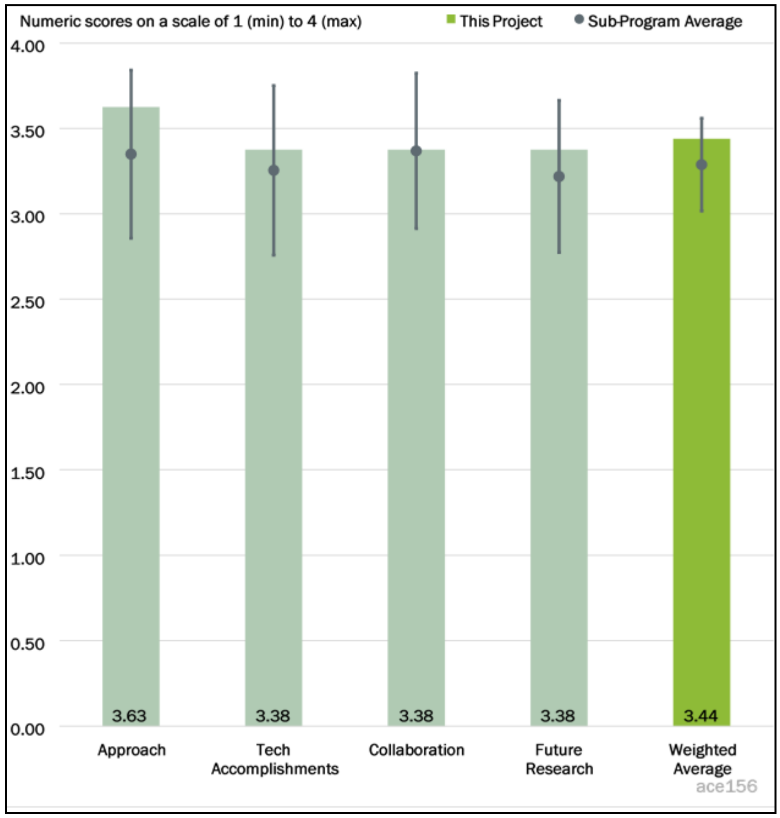

Figure 1-30 - Presentation Number: ace156 Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development Principal Investigator: Michael Shelby (Ford Motor Company)

Presenter

Michael Shelby, Ford Motor Company

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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:

By focusing the projects approach on lightweighting and increasing the compression ratio through knock mitigation, dilute combustion, and thermal management, the reviewer pointed out that the project is attacking the critical barriers to increased fuel economy. The approach of using lean combustion and advanced ignition (active pre-chamber) is a solid approach.

Reviewer 2:

It looked to the reviewer like the technical team has taken a good approach to evaluate the two novel combustion systems in parallel to understand challenges and benefits of each.

Reviewer 3:

The reviewer commented that combining advanced computational fluid dynamics (CFD) with single-cylinder engine development and then moving to final multiple-cylinder engines is a technically sound approach and represents state-of-the-art technology development.

Reviewer 4:

This reviewer indicated that project goals are well clarified, but the focus is more evident in the combustion work than the weight reduction work. It was not clear to the reviewer that the weight reduction effort is as central to the project as it seemed.

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 single-cylinder engine (SCE) development and testing appear to have been delayed by a combination of COVID-19 capacity restrictions and "the usual" technical challenges encountered when dealing with new technologies. It looked to the reviewer like the team is making good overall progress against the timeline, especially with the multi-cylinder engine (MCE).

Reviewer 2:

The reviewer commented that the project team has shown mass reductions in parts between 20% -43% by using advanced materials and composites and making some of the parts structural components. The total of 17% reduction in mass (surpassing the goal) is an impressive feat.

The extension of the EGR limit by 10% should help mitigate knock, and the reviewer looked forward to seeing the results of the single- and multi-cylinder testing.

Reviewer 3:

According to the reviewer, progress is good on the combustion side. The weight reduction effort to date seems light relative to the time since the project award.

Reviewer 4:

Significant progress has been made on the analytical work and SCE developments. However, there has not been too much progress on MCE. One of the big concerns the reviewer had is weight reduction. Currently, the project may face challenges if the weight gain from EGR and cooling systems is added into the total weight reduction goal. It may be too late to have any hardware modification to the final MCE platform since time is running short before project completion at the end of 2022.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that Ford has put together an impressive team and the collaboration and coordination has so far paid off.

Reviewer 2:

The reviewer stated that project team coordination is much stronger this year.

Reviewer 3:

It looked to the reviewer like FEV has been brought in as a fully engaged partner after a slow start and that ORNL is meeting its obligations as well. The reviewer also thanked the team for highlighting how many additional (parts) suppliers are engaged in the technology evaluation and the multi-cylinder engine prototype build.

Reviewer 4:

While FEV and ORNL are mentioned, the reviewer suggested that other companies should be acknowledged as pointed out by the presenter: more than 20 additional companies are engaged in the development since the space of the presentation is not a limiting factor.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The future work on this project looked sensible to the reviewer and achievable by the end of 2022.

Reviewer 2:

The reviewer commented that the proposed future work is tightly targeted at achieving the 15% mass reduction and 23% fuel economy improvement targets.

Reviewer 3:

The proposed future research seemed to be reasonable to the reviewer. It would be more thorough if research were done on how the risk can be mitigated after adding the weight from EGR and cooling system.

Reviewer 4:

The future plans are interesting. The reviewer remained unclear about the long-term potential for the projects under this DOE call.

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

Reviewer 1:

The reviewer stated that the advanced technologies investigated in this project will reduce carbon dioxide (CO_2) emissions and increase fuel economy of the powertrains found in light-duty (LD) vehicles. This research can be applied across many, if not all, LD vehicle platforms and will lower overall foreign energy dependence.

Reviewer 2:

The reviewer found that the project is aligned with the DOE objectives of the time.

Reviewer 3:

According to the reviewer, the project supports the overall DOE objectives by improving the engine, thus vehicle, fuel economy.

Reviewer 4:

There is a pathway to improved engine fuel consumption with the engine technology packages being considered. The reviewer asked for clarification about whether the fuel economy target is CAFE (unweighted FTP-75 cycle and Highway Fuel Economy test [HFET]cycle only) or sticker (two or five cycles but weighted to predict the fuel economy seen by drivers). It may not make a difference so long as the baseline and improved values are being calculated the same way.

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 are good.

Reviewer 2:

It looked to the reviewer like the program is adequately funded for the scope of work.

Reviewer 3:

The reviewer commented that the project team should have all it needs to complete the project.

Reviewer 4:

While the budget looks large, the reviewer noted that it is not when you consider the number of prototype parts that must be designed and assembled for this project in order to perform the engine testing. This is an impressive undertaking.

Presentation Number: ace158
Presentation Title: Slashing Platinum Group Metals (PGM) in Catalytic Converters: An Atoms-to-Autos Approach
Principal Investigator: Wei Li (General Motors, LLC)

Presenter

Wei Li, General Motors, LLC

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

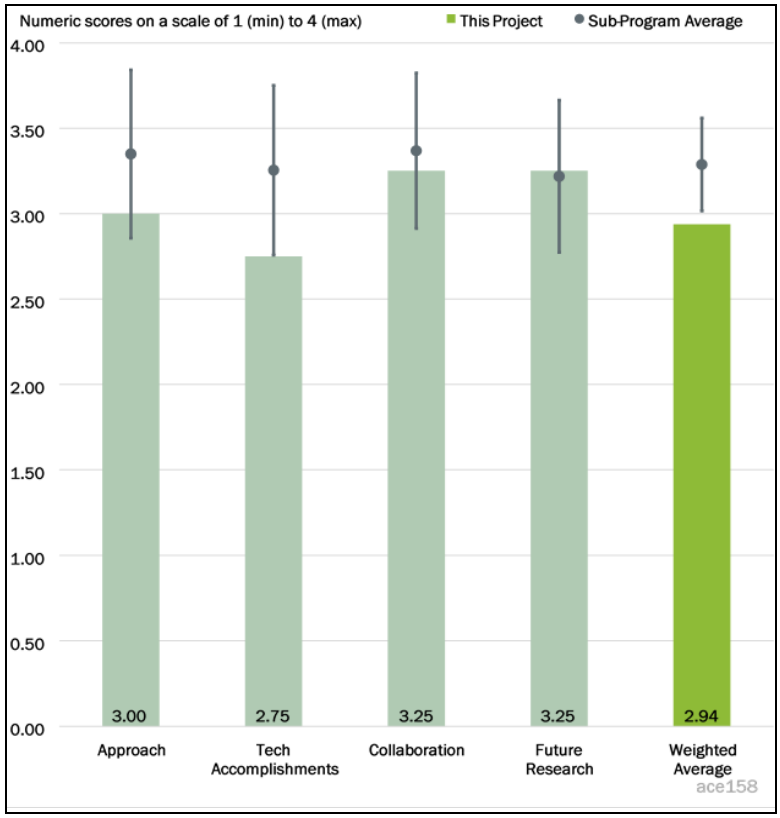

Figure 1-31 - Presentation Number: ace158 Presentation Title: Slashing Platinum Group Metals (PGM) in Catalytic Converters: An Atoms-to-Autos Approach Principal Investigator: Wei Li (General Motors, LLC)

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 understood that this project is in the early stages and probably also impacted by COVID-19. Having said that, the reviewer said that it will be good to broaden the baseline catalyst technology and asked several questions: Can another catalyst or vehicle combination be used to show the applicability of the technology to more than one catalyst? Is the catalyst currently zone coated? What about the impact of support (alumina, ceria, etc.) and substrate? Will sulfur resistance be included or should it be? Will oxygen storage be evaluated? There are many factors that need to be considered here.

Reviewer 2:

The reviewer appreciated the approach being deployed here, especially the aggressive aging procedure and recognition that single-atom catalysts have not shown high reactivity on their own (and thus they serve as agglomeration points). The reviewer thought that the starting point for the PGM loading for this project is also reasonable but was troubled by the two different projects using different starting points to show reduced PMG levels. Although the aging procedure is aggressive, the reviewer wondered if the project and community would benefit from a stepped approach to aging. With hybridization, it may be possible to limit high-temperature excursions, and the team could find a catalyst with ultra-low PGM that fails at 975°C. If the project team reports that this catalyst is good so long as this temperature is avoided, it would be good information to have.

Reviewer 3:

The reviewer stated that the approach briefly described the use of single-atom catalysts (SAC) and methods to slow platinum-group metals (PGM) sintering, which will help to reduce PGM use in three-way catalysts (TWC); however, limited details on this approach were given, making further assessment difficult.

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 remarked that little to no details were given on results to date, making it difficult to evaluate technical progress. The early stage of this project at the time of these slides is likely the cause, and the reviewer looked forward to seeing more results under relevant conditions in next year's presentation.

Reviewer 2:

The reviewer stated that the project has essentially been planned out, but no experimental results have been obtained or presented; thus, it is difficult to fully assess the true progress.

Reviewer 3:

The reviewer commented that there was not much detail so far to make comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that there was good coordination and task alignment to appropriate team partners. Partners are all well known for their respective capabilities.

Reviewer 2:

The reviewer remarked that this is an excellent team of researchers that brings a broad level of expertise to the project with extensive experience in emissions control research.

Reviewer 3:

The reviewer indicated that there is not much detail so far, but it looks like a good team.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said that a list of specific targets and go/no-go decision points was provided. Progress along this path will result in a successful project outcome.

Reviewer 2:

If successful, the proposed research will answer the question about viability of the TWCs developed here. As mentioned previously, the only concern the reviewer had was that the aggressive aging conditions may discard catalysts that may be of value if a lower temperature is not exceeded.

Reviewer 3:

There is a need to include the impact of sulfur resistance, washcoat support, substrate, oxygen storage, etc., to make this practical. Also, it was not clear to the reviewer whether the final goal includes coating on full-size monoliths and testing on a vehicle. That should be included.

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

Reviewer 1:

The reviewer commented that PGM prices are very high, and there need to be ways to reduce PGM usage.

Reviewer 2:

The reviewer pointed out that the project is specifically targeted at reducing PGM use by 50% in TWCs.

Reviewer 3:

Since indicators suggest severe PGM shortages are here to stay, the reviewer indicated that this research is important to alleviate these pressures and to identify solutions quickly.

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, funds are sufficient for this project.

Reviewer 2:

Resources seemed sufficient to the reviewer, and additional resources could be identified at the different industrial partners since this will likely affect their profitability.

Reviewer 3:

The reviewer encouraged the project team to please consider full monolith coating and vehicle testing (maybe already part of plan, but not clear).

Presentation Number: ace159
Presentation Title: Reduced Cost and Complexity for Off Highway Aftertreatment
Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

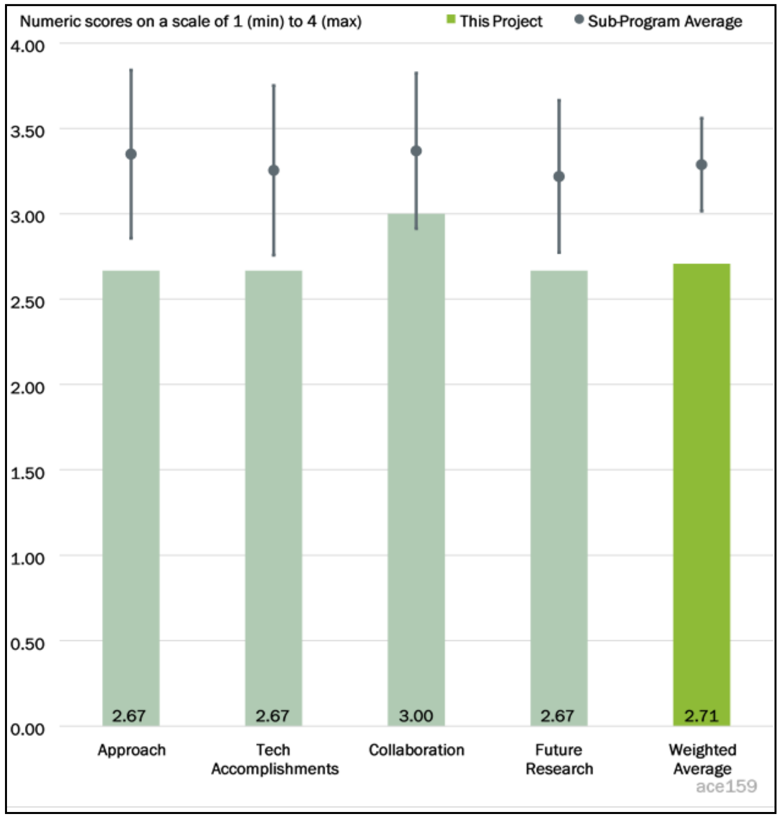

Figure 1-32 - Presentation Number: ace159 Presentation Title: Reduced Cost and Complexity for Off Highway Aftertreatment Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Presenter

Ken Rappe, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 called the approach good as it touches upon the main barriers and challenges for combining a diesel oxidation catalyst (DOC) and diesel particulate filter (DPF). It might also be worth emphasizing soot management as it was not clear to the reviewer how much work will be done on evaluating regeneration under various conditions.

Reviewer 2:

According to the reviewer, the goal to reduce the complexity and cost of the emissions control system is an important one to pursue. However, the reviewer was not certain how the approach proposed will result in a functional device without some standalone DOC upstream of the DPF. If successful, the team will deserve a lot of credit for finding a solution to soot build-up on the front of the combined DOC and DPF (DOCF). The soot is a known inhibiting agent and will create issues, but perhaps there are solutions. With that being said, there was little discussion of this issue, and most importantly no plan to study this phenomenon on the bench reactor. It will only become an issue when moving to engine experiments later in the project.

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:

It seemed to the reviewer that it is very early to comment on technical accomplishments, but the modeling work and engine selection look good so far.

Reviewer 2:

The reviewer understood that this project is just getting started and having results at this point would be difficult. However, this seems to build off work performed in a cooperative research and development agreement (CRADA), so it is not clear how this is differentiated from the CRADA and why the results from the CRADA could not be used here to indicate the direction of the research.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project team seemed good to the reviewer.

Reviewer 2:

There are a lot of good team members listed in the project with a lot of relevant experience. The reviewer was curious to see how the implementation of the spatially resolved capillary inlet - mass spectroscopy (SPACI-MS) approach goes, as this complex research tool can be difficult to deploy, and the team is lacking experience in this area.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the future work is good. The inclusion of full engine testing is very good. The reviewer encouraged the project team to please consider soot regeneration as part of the test matrix.

Reviewer 2:

As discussed in the approach, the reviewer was concerned about not including soot in the bench reactor measurements. Ford researchers have reported a way to make particulate in flow reactors, and this should be considered.

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

Reviewer 1:

He reviewer stated that reducing cost and PGM usage is going to be important especially as we move toward tighter regulations.

Reviewer 2:

The reviewer indicated that off-road emissions are an increasingly important sector that DOE should be supporting in emission control research, and this project fits that mold.

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

Reviewer 1:

The reviewer stated that the project is attempting to tackle a big problem from several fronts, and the level of support is sufficient to address the issues outlined.

Reviewer 2:

Resources looked sufficient to the reviewer.

Presentation Number: ace160
Presentation Title: Optimization and Evaluation of Energy Savings for Connected and Autonomous Off-Road Vehicles
Principal Investigator: Zongxuan Sun (University of Minnesota)

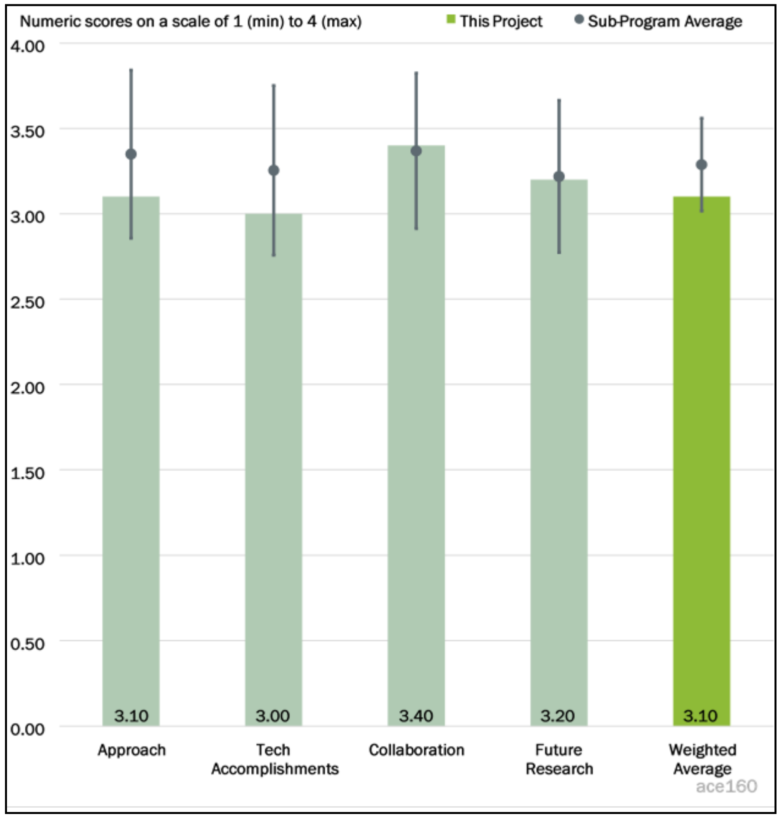

Figure 1-33 - Presentation Number: ace160 Presentation Title: Optimization and Evaluation of Energy Savings for Connected and Autonomous Off-Road Vehicles Principal Investigator: Zongxuan Sun (University of Minnesota)

Presenter

Zongxuan Sun, University of Minnesota

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 liked the way the project team presented the technical barriers of the engine's interaction with the propulsion and hydraulics. It is important to tie these together in the model. The reviewer believed the project is well defined and laid out, which should lead to success.

Reviewer 2:

The approach seemed good to the reviewer based on the initial outline, but the reviewer noted that it is a little difficult to understand what the approach will result as a deliverable. This may be due to the early nature of the project, and the validity of the approach should become clearer as the optimization controls ideas are fleshed out and clearly defined. The ability to validate the controls and automation on a hardware-in-the-loop (HIL) bench should be good enough to demonstrate the performance potential.

Reviewer 3:

Overall, the reviewer commented that this project does address two key points—fuel consumption optimization of autonomous, off-road vehicle, power system management; and driver optimization. Regarding the latter area, the reviewer asked whether the team plans to use global positioning system (GPS) for forward-looking vehicle control purposes. The reviewer noticed light detection and ranging (LIDAR) and cameras though did not see any reference to GPS. Also, for attempting to quantify overall fuel savings versus current product, it is not clear how soft soil effects (cone index of some nature) are incorporated into the model. One challenge with taking off-road vehicle performance and correlating it with a good vehicle model is the soft soil portion of the analysis.

Planned HIL testing will be valuable using representative vehicle load data from field measurements along with eventual actual field testing. The reviewer called this a very good project that should deliver quite a bit of understanding in both power system optimization and current state of the art (SOA) in off-road autonomous vehicles.

Reviewer 4:

The reviewer's synopsis of the project was that the development team is modeling a machine and some worksite and work cycle with the goal of figuring out a sequence of command inputs to perform the required work at the lowest energy and best productivity. After that, the development team will use HIL to evaluate energy savings. It was not clear to the reviewer how the tool part of the machine will be evaluated in the HIL. Based on that, is the reviewer questioned if the HIL is needed at all when there is not a tool portion.

Additionally, there is not much information provided on the worksite model. The reviewer assumed that this would include modeling the digging, but it is not called out explicitly. There is no mention of validating the worksite model. The reviewer assumed that this would be critical to trusting any productivity and efficiency improvements. Accurately replicating the powertrain and implement loads with a hydrostatic dynamometer might be a significant challenge.

Reviewer 5:

More information would be useful on what the optimization opportunities are for off-road applications. The reviewer asked if the idea is to put the primary powertrain in a maximum efficiency region by coordinating vehicle motion and work-tool usage. Some examples of typical usage and how this could be improved would be useful.

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 project team has made good progress developing and validating the models. The team has used data from 11 different cycles provided by CNH and has also collected around 70 channels of data to develop the models. The project only started last November but has already made good progress.

Reviewer 2:

The reviewer stated that the project is in its early stages and initial work is addressing milestones of the project, which has a predominate simulation focus.

Reviewer 3:

Machine modeling looks promising, and the accuracy looks good for the basic subsystems. Total plan model order reduction is good, but it was still not clear to the reviewer how much computation time is being saved.

The worksite simulation model and its validation need to be completed. The reviewer wanted to know what the variability of this model is, how that is going to impact the validity of efficiency improvements, and whether the team is going to model several different autonomous machines at the work site. These activities may be a significant undertaking.

Reviewer 4:

It looked to the reviewer like the accomplishments to date are satisfactory. The reviewer had a difficult time really understanding what the model is and what has been done beyond the starting point. and asked if the model is a Simulink model, a one-dimensional (1-D) code of some sort, or something based on script programming. The milestones seem to be achieved on time, but there is just detail lacking on the model to really understand if this is beyond satisfactory. Additionally, the reviewer asked the team to please describe the model order precisely, what was done to reduce the order, what assumptions were simplified, and how this impacts the ability for the model to be transferred to different operating cycles or different off-road architectures. The diversity of off-road applications and load cycles makes modular capability in autonomy and optimization very important.

The reviewer asked two questions. Firstly, can the team describe how this optimization will interact with the machine operator? Secondly, will the controls detect what is desired and dampen, limit, or alter the operator input somehow or will there be periods of automation that the operator can choose to enable somehow? How this really gets implemented in an operator and dynamic work environment was not yet clear to the reviewer.

Reviewer 5:

It was not clear to the reviewer if a diverse selection of worksites is envisioned.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer observed an excellent team, including the vehicle OEM that will oversee field testing.

Reviewer 2:

The reviewer commented that it was good to see that all parties are contributing and meeting every other week with the two universities and the entire team on a monthly basis.

Reviewer 3:

According to the reviewer, there is a good mix of university and industrial partners.

Reviewer 4:

The collaboration seemed good to the reviewer to get the initial model built with critical machine work cycles. The reviewer thought that once the HIL work begins, there will be opportunity for much more collaboration.

Reviewer 5:

It looked to the reviewer like the two universities are meeting bi-weekly, and the OEM is getting involved once a month. Caution needs to be made in model transfers and interfaces as different tasks will be performed at different universities.

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

Reviewer 1:

It appeared to the reviewer that everything is on schedule, and the plan is to have the HIL simulation up and running soon. It would be good to identify some potential problems and plan how to overcome them if they happen. A quote from one of reviewer’s colleagues when his project was behind schedule was that “There were more unknowns than we knew about.” The point is to give some thought to what could go wrong and how to overcome that.

Reviewer 2:

The impact of remote communication and variability might significantly affect efficiency and productivity. The benefit the reviewer saw from the proposed research is the development of the optimization technique, which should be robust enough to produce projected efficiency.

Reviewer 3:

The reviewer suggested encouraging the team to consider a diverse set of worksites to ensure this concept works across a range of use cases. Also, more definition is needed on what the opportunity is to better coordinate vehicle and work-tool functions via connectivity.

Reviewer 4:

The plan to finish the optimization and automation development and then transition to the HIL work is clear and what is required for the program goals and objectives. The reviewer proposed that the team please consider how it needs to interface with the machine operator in the HIL work.

Reviewer 5:

The future research plan is logical and focused on project goals. One suggestion from the reviewer is to consider a transient cooling model to better address possible fuel savings though this is dependent on vehicle OEM measurements concerning parasitic losses in thermal management systems. Also, closer attention to soil mechanics could be very helpful, too.

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

Reviewer 1:

According to the reviewer, there is the potential for a 30%-40% efficiency gain in material handling with this technology. If this is successful, it will greatly reduce the fuel consumptions for these applications where this can be applied. Also, going all the way to autonomous would save on labor costs.

Reviewer 2:

The reviewer noted that connectivity is a good fit to off-road applications.

Reviewer 3:

The reviewer responded that, yes, reducing fuel consumption in off-road machines directly goes to the DOE's energy security and emissions reduction objectives.

Reviewer 4:

The reviewer commented that the proposed technology is aiming to increase the energy efficiency of the wheel loader. The amount will heavily depend on the baseline model and variability of the cycle.

Reviewer 5:

The reviewer observed a good project that combines power management optimization with autonomy improvements in energy use. One concern is that the latter autonomy pieces may inhibit the findings of this project, e.g., barriers in latency and sensing could limit vehicle capability at high work-site operating speeds. Nevertheless, combining both thrusts in a reasonable approach.

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

Reviewer 1:

Resources seem to be about right. The reviewer expected much of the work is modeling so that requires supporting one or two graduate students and plans to do HIL, which is cost effective. The project seems to be a good value.

Reviewer 2:

It seemed to the reviewer that all parties in this project have sufficient resources for the proposed future work and the engagement of OEM, and the two universities are good.

Reviewer 3:

To date, the reviewer commented that the resources seem to be sufficient to complete the milestones on target. The HIL work may take more resources, but that will develop in the next budget period.

Reviewer 4:

Resources are in place to complete this project, according to the reviewer.

Reviewer 5:

No comment was indicated by this reviewer.

Presentation Number: ace161
Presentation Title: New Approach for Increasing Efficiency of Agricultural Tractors and Implements
Principal Investigator: Andrea Vacca (Purdue University)

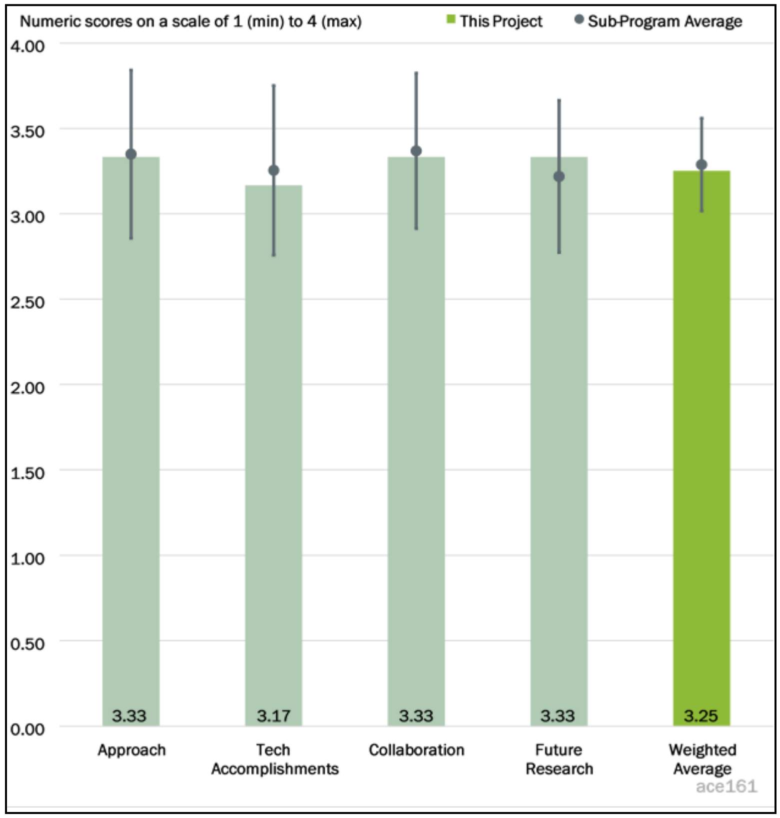

Figure 1-34 - Presentation Number: ace161 Presentation Title: New Approach for Increasing Efficiency of Agricultural Tractors and Implements Principal Investigator: Andrea Vacca (Purdue University)

Presenter

Andrea Vacca, Purdue University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 this to be a very interesting concept and approach for converting from flow control to pressure control with the multi-pressure rail (MPR) system optimization. It has great potential, and the reviewer would like to see this project move forward.

Reviewer 2:

According to the reviewer, the approach of getting the baseline data is good, and the results show a good match between the model and the measured data.

Reviewer 3:

The technical approach is quite interesting. It was not clear to the reviewer how all the efficiency gains will be achieved but the reviewer would be interested to see the future developments

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 remarked that fantastic progress is being made toward achieving the defined project milestones and encouraged the project team to keep it up.

Reviewer 2:

The project just started in the past fiscal year so the results to date are hard to evaluate. The reviewer hoped that progress is accelerating.

Reviewer 3:

This project seemed to the reviewer to be making good progress. There is a potential to achieve predicted efficiency with the increase in circuit complexity. However, the market may be reluctant to take on the cost increase, which needs to be followed on. Eventually, the project team should explain how the pressure levels for High, Medium, and Low-pressure rails are chosen. It seems that the planter application has the most opportunity for potential savings, but the reviewer suggested that an aggregate cycle be studied.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found excellent collaboration across the project team, which is leveraging expertise from university, national laboratory, critical component supplier, and OEM staff. The reviewer called the effort well done.

Reviewer 2:

The communication level is good among all the partners. It seemed to the reviewer that the partners are sharing data well, and having the machine available at the principal investigator's (PI) location is also a big plus for this project.

One point of concern and a suggestion is related to making sure that the communication of requirements for controls development (as part of the future work) stays strong as the National Renewable Energy Laboratory (NREL), Purdue, and Case are all involved.

Reviewer 3:

It was hard for the reviewer to tell how much interaction there is between the partners so far.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented that fluid power efficiency needs to improve, and the project goal is well aligned with this need.

Reviewer 2:

According to the reviewer, the proposed future research is effectively planned. However, there are some key barriers with regard to commercialization and customer acceptance that should be addressed, such as the packaging plan as well as implementation challenges for customers with mixed tractor-implement fleets.

The implement is self regulating and will get what it needs, and peak demands often drive system design and optimization. The reviewer asked how the project team could ensure that the MPR system will be optimal for a given production system when the system is operating below the peak for most of its duty cycle.

Reviewer 3:

Future technical work looked appropriate to the reviewer. There is a need to emphasize again that the market analysis and ability to create enough customer value with the proposed approach is well understood and that the proposed solution is realistic. The reviewer wanted to know what the assumptions are for the payback period.

Space claim is a challenge on agricultural tractors. The reviewer asked if a packaging study is planned to help downselect from the various concepts.

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

Reviewer 1:

By targeting technologies and concepts that will double the energy efficiency of the overall hydraulic transmission system of tractors and their implements through the reduction of throttling losses, this project supports the DOE objectives to de-carbonize the agricultural sector while providing savings to farmers as well as a transition to a clean energy economy.

Reviewer 2:

The reviewer found good alignment.

Reviewer 3:

The proposed technology seems to increase the energy efficiency of the tractor-implement hydraulic system. The reviewer was not sure that it will "double it," and that is yet to be proven in an aggregate tractor cycle.

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

Reviewer 1:

Resources seemed good to the reviewer.

Reviewer 2:

The reviewer noted that the project spend is on track.

Reviewer 3:

It seemed to the reviewer that all parties in this project have sufficient resources for the proposed future work.

Presentation Number: ace162
Presentation Title: Improved Efficiency of Off-Road Material Handling Equipment through Electrification
Principal Investigator: Jeremy Worm (MTU)

Presenter

Jeremy Worm, MTU

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 33% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

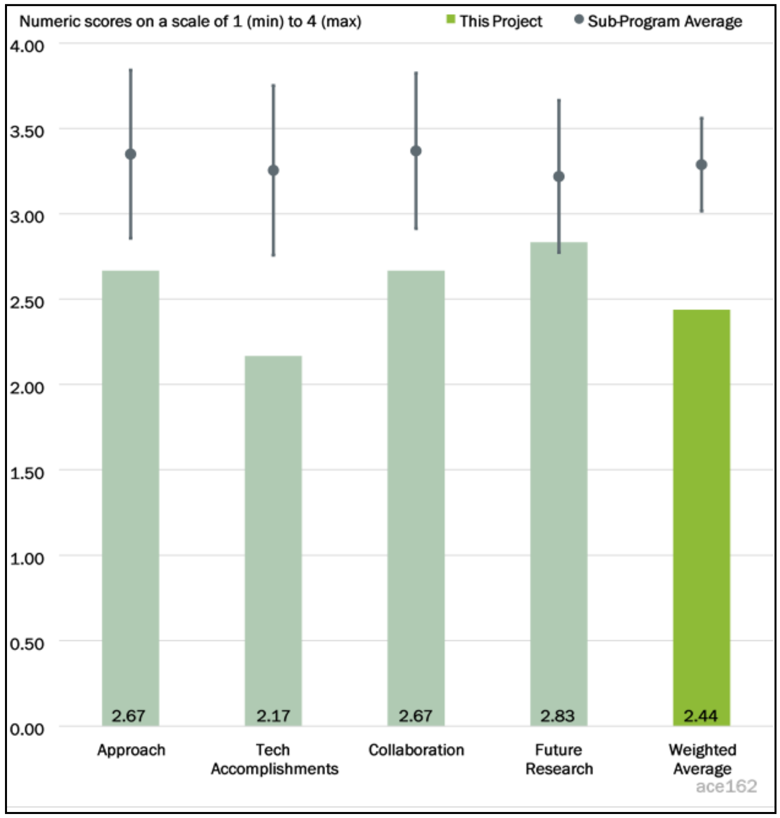

Figure 1-35 - Presentation Number: ace162 Presentation Title: Improved Efficiency of Off-Road Material Handling Equipment through Electrification Principal Investigator: Jeremy Worm (MTU)

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 project is reasonably well defined and has some potential due to the criticality of material handling.

Reviewer 2:

The reviewer remarked that the hydraulic system modeling data are not available, which will cause the PI to struggle to get accurate baseline models, which in turn will not provide good machine baseline performance. Additionally, lack of the machine application data may yield an incomplete understanding of the machine and component requirements. It was surprising to the reviewer to see that the OEM does not have any machine application data that would be useful for this project.

Reviewer 3:

The reviewer indicated that some discussion on the type of electrification envisioned (full battery electric versus hybrid) 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 reviewer remarked that not much progress has been made on this project due to some understandable delays and encouraged the project team to please keep working through the challenges.

Reviewer 2:

The reviewer stated that the project is off to a slow start but agreed this is a good application to consider electrification.

Reviewer 3:

The reviewer said that this project has had significant delays and indicated that the uncertainty of project completion is very high. The reviewer was concerned that subcontracts are not yet complete and that the partner has not re-created the technical documentation for the machine hydraulic system. The project is stating that the improvements will be done "through electrification," so the reviewer inquired about some of the electrical architecture concepts.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that a strong project team has been assembled with partners representing all relevant subsystems.

Reviewer 2:

According to the reviewer, more work needs to be done across the project team, especially with the OEM partner on key project inputs such as obtaining real-world duty cycle information instead of developing representative duty cycles based on a video of a working machine. The duty cycle is a critical input for designing an optimal electrification architecture.

Reviewer 3:

It looked to the reviewer like the OEM is not providing enough support and the PI needs to send the machine to an end-user to collect the baseline data, which will further slow down this development. In addition, this is the only one of the possible applications. The conclusion obtained from this site may not be sufficient to understand the full picture of the machine applications.

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

Reviewer 1:

The plan outlined for the project was reasonable to the reviewer, who expressed interest in getting some confidence that the project team can effectively execute in a collaborative manner. The reviewer encouraged the team to please keep working through the challenges.

Reviewer 2:

The reviewer inquired whether the project team should consider applications other than material handling so that the electrification system developed has the broadest possible application.

Reviewer 3:

It looked to the reviewer like the future challenges with modeling will continue. Again, there are no details about electrification circuits and components. The reviewer commented that the percent complete for the project does not line up with the milestones or the content provided in the overview.

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

Reviewer 1:

According to the reviewer, the demonstration of 20% reduction in fuel economy for a critical application like material handing will support the overall DOE objectives to de-carbonize the industrial sector and transition to a clean energy economy.

Reviewer 2:

In general, the reviewer noted that these types of applications (intermittent usage, high potential energy) should be studied for best form of electrification and hybridization.

Reviewer 3:

The reviewer stated that the project supports the general idea of energy saving and seems like an interesting project but one lacking in detail and progress.

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

Reviewer 1:

Team assembled looked appropriate to the reviewer to get the job done.

Reviewer 2:

With little progress made so far in this project, the reviewer indicated that there are sufficient funds left to execute the project.

Reviewer 3:

The reviewer remarked that it looks like the OEM is not providing sufficient support and adequate data.

Presentation Number: ace163
Presentation Title: Ducted Fuel Injection and Cooled Spray Technologies for Particulate Control in Heavy-Duty Diesel Engines
Principal Investigator: Adam Klingbel (Wabtec)

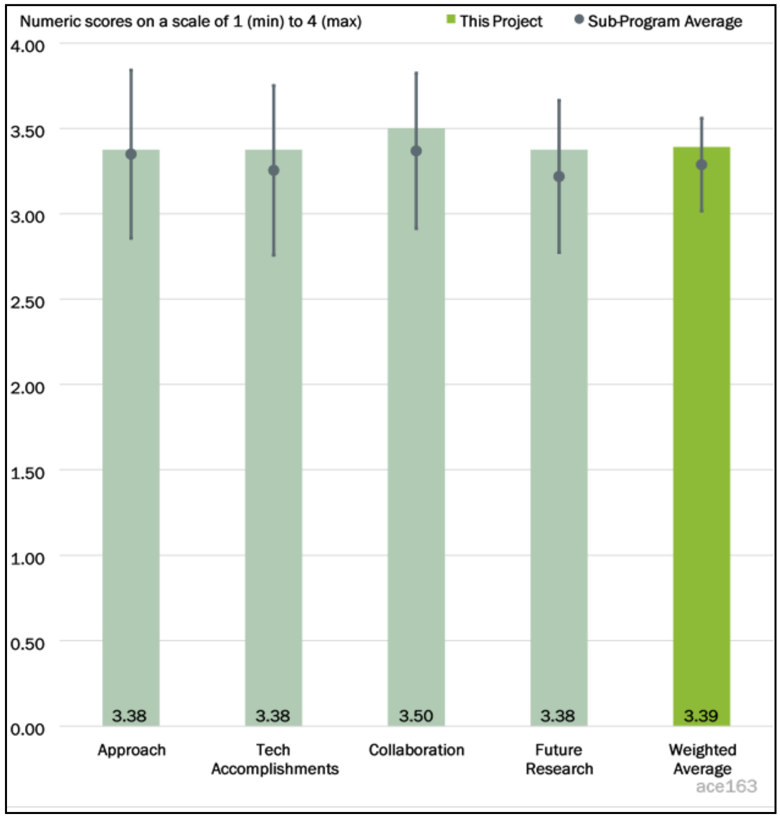

Figure 1-36 - Presentation Number: ace163 Presentation Title: Ducted Fuel Injection and Cooled Spray Technologies for Particulate Control in Heavy-Duty Diesel Engines Principal Investigator: Adam Klingbel (Wabtec)

Presenter

Adam Klingbel, Wabtec

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 indicated that the approach to use both optical engine work and metal engine work is outstanding to help bring the strengths of each toolset together. The reviewer believed there will be great power in taking the surprises from the metal engine and trying to replicate and understand them better in the optical engine. The timeline and scope all seem well designed and feasible within the project timeline and budget.

Reviewer 2:

The reviewer remarked that the approach is to utilize similar technologies in-cylinder to enhance premixing of fuel and air to reduce PM production. The approach, if successful, should result in a substantially altered soot and NO_x tradeoff, allowing for use of more EGR to control NO_x while not penalizing the engine on PM. The project looks to be studying the relevant scientific principles, and the proposed work should go a long way in establishing the viability of these technologies. However, some off-road vehicles sometimes struggle with high levels of EGR due to the general lack of ram-air cooling for EGR coolers. These proposed technologies may be significantly less effective in those applications.

Reviewer 3:

The reviewer stated that the overall approach is very good: evaluate metal engine and optical engine results sharing similar combustion system designs and iterate on possible additional solutions based on these results.

One element that is missing and might be useful is spray modeling as an aid in choosing duct length and diameter design options. There are possibly good reasons for not including this element.

Reviewer 4:

The reviewer found very limited detail provided on the approach to the work, or even the justification, outside of the reduction in PM claimed.

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 remarked that two of the scheduled milestones were completed with the only other milestone having a 1-month delay, which is very good for a newly launched project still dealing with the residual effects of the COVID-19 pandemic. Evidence of excellent progress is that many of the new designs are complete, with some components already purchased and procured. The new fiber optic alignment technique is also excellent as it may be critical for both successful lab experiments and for production manufacturing.

Reviewer 2:

Since the project initiated in October 2020, it was difficult for the reviewer to accurately assess project progress. However, there does appear to be a significant amount of technical progress even in the limited time the project has been active. There are already hardware pieces and test cells prepped for testing engines using these technologies.

Reviewer 3:

In all fairness, the reviewer commented that this project has recently begun and that is why just a good rating was chosen. It is too early to make a fair judgment right now.

Reviewer 4:

The reviewer noted that the project progression is in its very early days.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The different partners on this project appeared to the reviewer to be very well coordinated, and close collaboration has allowed for the substantial progress even to date. Southwest Research Institute (SwRI), SNL, and Wabtec all look to be on the same page.

Reviewer 2:

Being that there are three core teams working on this project (Wabtec, SNL, and SwRI) the collaboration seemed excellent thus far to the reviewer. The plan to coordinate metal and optical engine work will necessitate excellent collaboration as data and learning progress with the future work.

Reviewer 3:

The reviewer found the team to be a good mix of metal and optical engine expertise. Collaboration could be extended to another entity such as possibly a university if CFD were added to this work effort for further iterating on various duct designs.

Reviewer 4:

The reviewer noted that there was limited information on what other team members have actually achieved. The plans are clear, but progress is early.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer pronounced as outstanding the metal and optical engine approach toward future convergence of the optimal duct design. One suggestion as mentioned above is to include CFD analysis for aiding duct design iterations.

Reviewer 2:

The reviewer noted that this work looks to address both scientific understanding and commercial application, which is an excellent combination. The decision to try to understand the "scaling" of DFI and cooled spray (CS) was a very good one since this will allow for a broader evaluation and application of these technologies in the future. However, it remains to be seen how easy it will be to manufacture either of these technologies on a large scale. Even if the project is successful, it will be necessary to chart a course on how to take either or both of these technologies out of the lab and into the factory.

Reviewer 3:

The proposed future work all seemed very logical to the reviewer, with no gaps in real areas. Obviously as the preliminary data on CS from the metal engine emerge, there will need to be adjustments in the future research.

There was a question about the difference between CS and ducted fuel injection (DFI). DFI is widely discussed in the literature as generally just a duct placed near the injector nozzle exit. The reviewer inquired as to whether the project team could describe what the CS concept is doing that is inherently different in the near nozzle region from DFI. It seems like Wabtec has had good success with soot reductions with the present form of CS, but to achieve the goals of scaling laws for various engine sizes the physics of this concept needs to be elucidated clearly. the reviewer did not know how this CS physics description can be disclosed sufficiently while retaining the confidentiality that Wabtec would clearly want to protect. The reviewer suggested that the team please think about how to best make the information useful for this publicly funded project.

Reviewer 4:

The justification for the spray ducting is apparent, but the justification for CS was less so to the reviewer, who asked why that was important.

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

Reviewer 1:

The reviewer stated that there is significant benefit in reducing the emissions level for off-road vehicles by using potentially inexpensive technologies. Many off-road vehicles are not easy to electrify, so engine technology advances are needed in this area.

Reviewer 2:

Providing reduced cost emissions reductions technology is clearly aligned with DOE's objectives for off-road power systems, according to the reviewer.

Reviewer 3:

The reviewer remarked that this project is a very straightforward hardware design and evaluation effort focusing on PM reduction based on past demonstrated experimental efforts. This project should provide an excellent assessment of ducted fuel injection and its capability to dramatically reduce PM.

Reviewer 4:

The reviewer commented that improving the IC engine remains an important part of energy efficiency in the automotive area.

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 budget seems sufficient as the project goals are fairly modest.

Reviewer 2:

The resources allocated to this project appeared to the reviewer to be satisfactory to allow for success in a timely fashion.

Reviewer 3:

The work scope and plan seemed to be feasible to the reviewer with the given budget and collaborator resources.

Reviewer 4:

No comment was indicated by this reviewer.

Presentation Number: ace164
Presentation Title: Improving Efficiency of Off-Road Vehicles by Novel Integration of Electric Machines and Advanced Combustion Engines
Principal Investigator: Sage Kokjohn (University of Wisconsin)

Presenter

Sage Kokjohn, University of Wisconsin

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

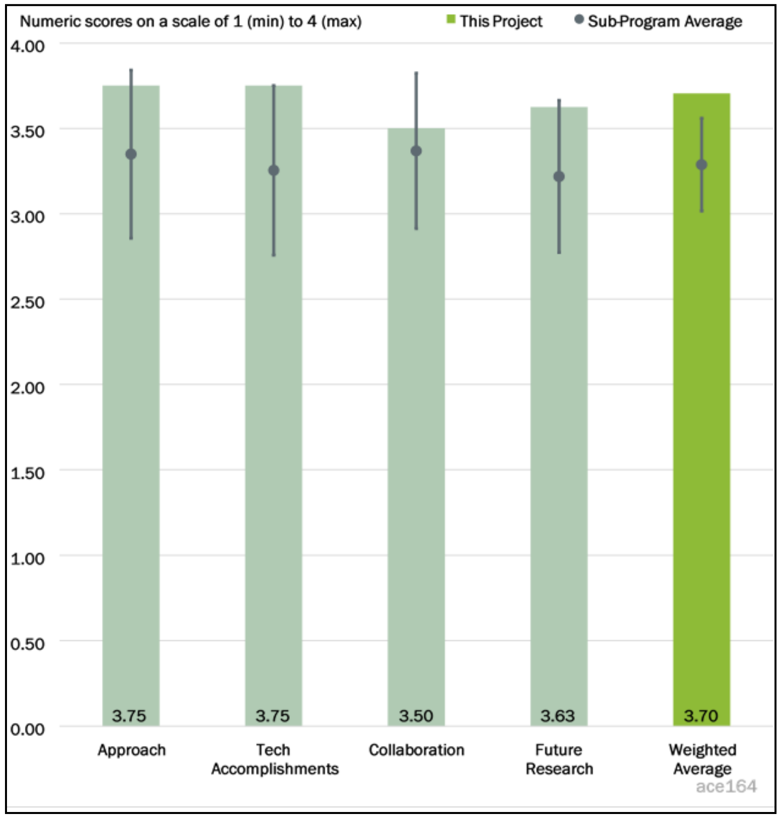

Figure 1-37 - Presentation Number: ace164 Presentation Title: Improving Efficiency of Off-Road Vehicles by Novel Integration of Electric Machines and Advanced Combustion Engines Principal Investigator: Sage Kokjohn (University of Wisconsin)

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 project concerns a strategy for improving fuel efficiency of off-road vehicles—tractors, farm equipment, etc. The importance of this undertaking is that this transportation is as high as high as 8% of the total energy consumed in the U.S. transportation sector. The primary piston engine employed in this sector is the diesel engine with its concomitant potential for creating harmful emissions during operation that include greenhouse gases, particulate matter (i.e., soot), oxides of nitrogen and other toxic gases. The obvious approach to mitigate these concerns is full electrification. However, the PI has considered that this approach is unlikely to be viable, likely due to concerns over battery development and the loads expected on the machinery from the typically harsh environment of operation. The PI's approach is to hybridize the off-road frame with the goal of downsizing the engine and optimizing combustion. This project was started in 2019, and this is apparently the first year for its review.

The PI's approach includes modeling, engine experiments, and vehicle testing. A specific platform was selected with an engine size of 6.8 L (the baseline), which the PI is downsizing to 4.5L.vThe reviewer stated that the approach is well conceived and has good promise.

Reviewer 2:

To date, there has not been much research into electrification into off-road vehicles, and the reviewer thought that it is important to support work in this area. One barrier not discussed was that the project team is using light- and medium- duty on-road parts for the off-highway environment. In the future, the reviewer suggested that the team may need to address the reliability and durability of these parts for the off-road vehicles, even though the reviewer knows that this is beyond the scope of this initial investigation. Overall, the approach looks good and is well laid out and very feasible.

Reviewer 3:

The reviewer called the approach to this project very solid: developing a vehicle-level model; validating the model against data; modifying the drivetrain to evaluate different hardware, including turbo geometries and hybridization schemes; narrowing the testing matrix; and testing the resulting systems for efficiency and cost effectiveness. The work performed to date has been well done and evaluated through several industrial partners to ensure success in real-world applications.

Reviewer 4:

This reviewer inquired whether hybrid systems should be considered, such as parallel hybrid in addition to series hybrid. This could allow for downsizing of the electrical system as the engine contributes directly to drive shaft power.

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 remarked that the project just started in October 2019, and the baseline modeling and simulations have been completed. The project team has shown that it is possible to downsize from the 6.8L to the 4.5L engine. So far, the results look promising. The team is scheduled to have a front-end loader provided to the project so it looks not only like there will be good progress on the next milestone but also a demonstration during the final budget period.

Reviewer 2:

The project team's progress is up to date and on target, according to the reviewer. The team has an impressive and aggressive set of goals that are currently on target and achieving a high degree of success. A potential 17.6% efficiency increase is impressive.

Reviewer 3:

Optimizing engine displacement is an important consideration. It seemed to the reviewer that the project settled on a 4.5L displacement, and the reviewer asked if there had been a study done to show this is optimal from an overall efficiency standpoint. As the eBooster and eTurbo consume electrical power, the reviewer wanted to know if this is the best usage of that electricity or should it be better used for shaft work.

Reviewer 4:

According to the reviewer, the PI and the project team have done a lot in a short amount of time. The work has already shown a significant reduction of soot with the eBooster.

There are a number of questions the reviewer posed that should be considered as the project advances:

- The modeling will need to be better explained. Considerations of the model inputs— kinetic mechanism, soot model, and how these elements were validated along with predictions of in-cylinder transport—should be discussed in future modeling. With a system as complex as the vehicle considered, it was not clear to the reviewer how a system-level model would be able to provide quantitative predictions, given the significant complexity of in-cylinder transport. This should be explained.

- The PI notes "machine learning" for the soot model. This needs clarification.
- The Gaussian process regression (GPR) model should be discussed.
- Presumably, a diesel surrogate is being used, correct? There should be discussions of how it was formulated and validated.

This project work has employed a lot of testing and simulation over the past year, and the results have shown some promising trends (e.g., 21% reduction of particulate emissions). The project team should consider how to generalize work to not only address the specific engine system being developed but also to provide results on mechanisms and processes that could guide performance evaluation for other designs. In the absence of attempting to understand the processes, the results of the project could be overly narrow and not extendable to other off-road systems. The ability to do this could rest on the efficacy of the CFD modeling work. Validation is also key, and that too should be discussed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project team has monthly calls. Initially, the reviewer had the impression that the University of Wisconsin and John Deere are heavily involved in the first part of the project and Purdue will be collaborating more in the near future when that university will be responsible for the handling the supervisory controls and software for demonstrating in a vehicle. Overall, there is good collaboration.

Reviewer 2:

The reviewer commented that the really good progress for the first year of this project is evidence of a highly functional cross-organization team.

Reviewer 3:

The presenter listed four team members, two of them at University of Wisconsin (UW)-Madison (UW-Madison) (Mechanical and Electrical departments), which the reviewer indicated can have the potential to lead to good collaboration on the project as proximity is not an issue. John Deere is an excellent source for cost and operational data. Purdue's participation is also a good partner for controls work. The only collaboration that is missing is a powertrain parts manufacturer for a more direct pipeline for parts needed for testing. This can be overcome due to the project's use of John Deere. All in all, this is an excellent group, which by all accounts looks to be working well together.

Reviewer 4:

The lead for the project is UW-Madison. The university is responsible for the electric machine and combustion system analysis. Collaborators are John Deere and Purdue. The John Deere collaboration is good, especially because they have provided some data against which the PI could compare their system-level simulations. In fact, Slide 6 shows some impressive comparisons. The reviewer suggested that further details should be provided regarding what is needed for the solution to be carried out (e.g., turbulent transport, detailed combustion chemistry, a surrogate model, soot model, and how the various inputs were separately validated).

The reviewer requested that the PI should provide some details of the Purdue component, which is stated to be "powertrain control." The reviewer wanted to know. specifically, what that will involve. UW-Madison has extensive engine testing facilities; the reviewer asked what unique elements the Purdue component provides to the project.

The project team is well conceived. However, it was not evident to the reviewer that the collaborators cover issues related to matters related to the battery. This is a crucial element that could impact the overall success of developing hybrid off-road vehicles. A recommendation would be to bring on a collaborator with expertise in battery development.

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. Note: if the project has ended, please state project ended.

Reviewer 1: .

The reviewer noted that this is the first year of the project, which has made significant progress and accomplished significant results. Looking at the progress and results, the goals and pathway of the research are logical and well planned out. The only missing piece (which could be follow-on research) is the effect of hybridization on cold-start emissions and aftertreatment effectiveness. Data from this study could enable an excellent investigation into the emissions effects of this work.

Reviewer 2:

According to the reviewer, the researchers have a good plan and schedule to meet the final vehicle demonstration. Most of the work will be in simulating the system and eventually validating with an actual engine in the test cell with the eBooster. One barrier that will be addressed is cost. The technology needs to be cost effective before OEMs will consider pursuing for production. This will have to be weighed against the competing technologies. There may be other technologies that can deliver more than an 8% fuel economy benefit.

Reviewer 3:

This is a very relevant project, and the reviewer asked that the project team should please ensure that the vehicle is tested over a full range of usage profiles so the hybrid system. power level, and battery size settled on are relevant to a range of applications.

Reviewer 4:

The reviewer commented that the future plans are well conceived and make sense, though they are rather broadly conceived. The proposed plan for continuation includes validating simulations about which the PI has already provided some results (e.g., Slide 6). As noted previously, validation should also include some aspect related to inputs to the simulation, such as the soot model, kinetic mechanism, surrogate, etc.

The success of the project, as likely with development of any hybrid vehicle, may be impacted by the available battery technology and associated issues (e.g., charging rate, battery size and capacity, safety [e.g., risk of explosions, battery thermal management]), etc. The reviewer remarked that off-road vehicles of the type considered in the project will be subjected to potentially harsher environment than on-road vehicles. The work plan does not seem to consider this potential concern. The PI's perspective (Slide 3) that "energy storage is expected to be available" might be oversimplistic. For that reason, a collaborator with expertise in the battery development community might be a worthwhile addition to the project.

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

Reviewer 1:

The reviewer stated that this project supports DOE's broad objectives of improving fuel and engine efficiency and reducing consumption of petroleum-based fuels. Hybridization of off-road systems is an important and not well studied technology. The goal of improved fuel efficiency of this sector is thus highly relevant to DOE's mission.

Reviewer 2:

The reviewer indicated that this is exactly the type of work that needs to be done: vehicle-level demonstrations to determine best level of hybridization from a cost-benefit standpoint.

Reviewer 3:

The reviewer remarked that the main objective of the project is to improve vehicle fuel economy and reduce greenhouse gas emissions. The goal is to reduce fuel consumption by 10% with no or improved vehicle operation.

Reviewer 4:

The reviewer said that off-road vehicles and equipment use 8% of U.S. energy in the U.S. transportation sector and cannot be fully converted to electric drivetrains due to their operational requirements. Implements used by these vehicles are, however, becoming more electrified. It would make sense to hybridize these vehicles to allow for efficiency gains.

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

Reviewer 1:

The reviewer thought that the dollar amount and the personnel resources are sufficient. A good portion of the work is simulation; in the near future the project team will be validating the models with engine testing and finally a vehicle demonstration. The vehicle demonstration will take considerable support from John Deere, but that company has been known to provide good support on past projects.

Reviewer 2:

According to the reviewer, the resources appear to be sufficient.

Reviewer 3:

The reviewer noted that there had been great progress by the team this past year.

Reviewer 4:

The resources seem adequate, though without more details (e.g., overhead rate, scientist and technician salaries, equipment costs, etc.) beyond the bottom-line costs for the project provided in the presentation, the reviewer is not qualified to adequately score this category. An ultimate judgment would have to come from a cost-benefit analysis based on DOE’s investment relative to the commercialization potential of what the PIs are pursuing.

Presentation Number: ace165
Presentation Title: Advancing Simulation Tools for Heavy Duty Engine Combustion Using X-ray Diagnostics
Principal Investigator: Gina Magnotti (Argonne National Laboratory)

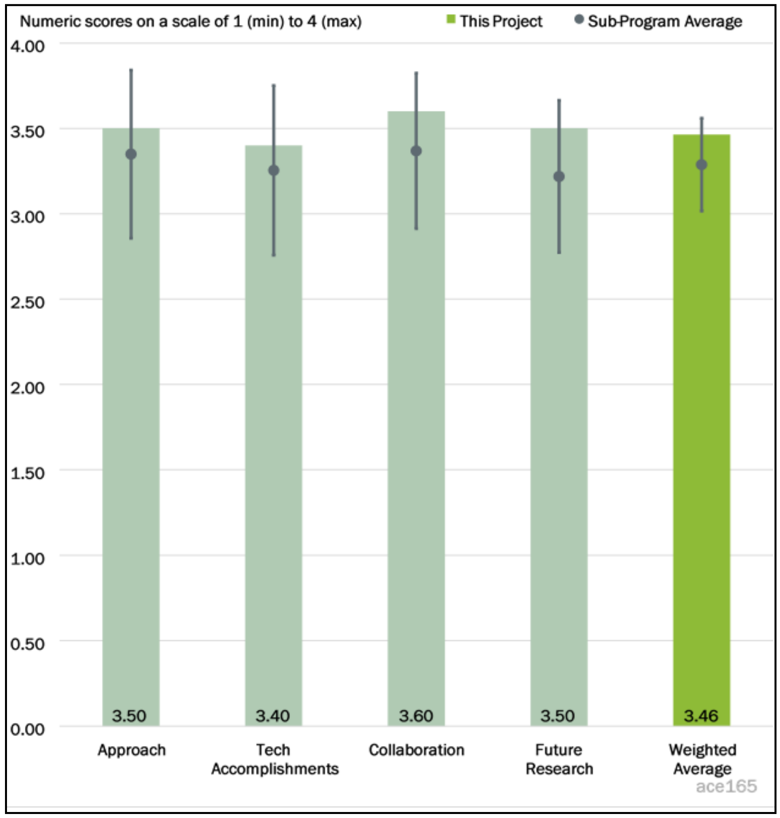

Figure 1-38 - Presentation Number: ace165 Presentation Title: Advancing Simulation Tools for Heavy Duty Engine Combustion Using X-ray Diagnostics Principal Investigator: Gina Magnotti (Argonne National Laboratory)

Presenter

Gina Magnotti, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 is a major fuel injection program that has been on-going since 2017, and the project team keeps expanding the scope of the program. The reviewer liked the idea that they “Develop, Apply, and Share” with others. For the Development part, they are investigating the fundamental spray parameters that need to be known to improve the spray and combustion models. The Apply part is to apply the information to create cleaner and more efficient engines. Finally, they are working with Converge to incorporate their models into commercial software that will be available to all. The reviewer liked the overall theme.

Reviewer 2:

The reviewer noted that the overall approach to provide simulation tools for accurate prediction of heavy-duty engine spray-combustion seems reasonable, which is supported by unique X-ray spray diagnostics and advanced combustion solvers.

Reviewer 3:

The reviewer commented that the joint simulation and experimental effort is the correct methodology for predictive spray model development. The Develop, Apply, and Share tag line hits well.

Reviewer 4:

According to the reviewer, the very clear approach to Develop, Apply, and Share is outstanding. It is very evident that the approach is intended to transfer the knowledge and the simulation tools to the industry end-users.

Reviewer 5:

It looked like the approach is reasonable to the reviewer. However, the injector nozzle erosion is highly stochastic, with a lot of parameters from operating conditions. The approach seems to be limited with predictivity. A consideration of stochastic erosion pattern would help the industry better.

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:

Over the years, the reviewer pointed out that great accomplishments have been made in spray and combustion modeling. The models are well received by industry, and many in industry are following your progress. The collaboration with Cummins and Converge and their use of the software is evidence of its importance.

The reviewer also thought that the erosion rig and erosion modeling are important to understand how emissions may change over time.

Reviewer 2:

Progress was made with a new injector cavitation rig and the ANL flamelet solver. The reviewer said that it will be exciting to see the link between erosion and combustion and emission behavior.

Reviewer 3:

The accomplishments seemed solid to the reviewer, who offered the following points:

- Referencing Slide 6, it would have been better to show how the cavitation-induced erosion risk assessment (CIERA) tool correlates against the measurement. The CIERA tool has been around for a few years, so the reviewer wanted to know what the plan is for further validation and development of the tool (second bullet).
- Referencing Slides 9-11, the measured nozzle erosion pattern is a decisive factor of the result. The whole process needs to be extended upstream to take into account the random erosion in the real world over broad operating conditions.

Reviewer 4:

It was rather surprising to the reviewer that the most advanced combustion model with large eddy simulation (LES) cannot predict in-cylinder heat release rate reasonably. It will be an issue for very low fidelity in engine performance prediction if this is the case for a real engine simulation.

Reviewer 5:

This reviewer observed excellent progress that is clearly demonstrated by the new erosion facility build at ANL; unsteady flamelet progress variable (UFPV) flamelet solver simulation producing approximately 25% reduced central processing unit (CPU) over well-stirred reactor multi-zone (WSR-MZ) models; end-to-end spray-to-combustion simulation toolchain development; volume of fluid (VOF) and Euler-Lagrange spray atomization (ELSA) validation with direct numerical simulation (DNS); and initiation of the new four-way CRADA.

It was clear to the reviewer that, with the CRADA, there is an industry first adopter for the end-to-end simulation toolchain, but the reviewer wondered how the adoption of this will be seen for others than Cummins. Industry has simulation plus experiment solutions today that vary based on need and desired simulation output, which may be cheaper or easier. Maybe the project team can plan to show how the end-to-end toolchain can be adopted or how it can provide clear benefits. The reviewer asked about how the injector design and operation gets integrated into the injector flow simulation. These are typically done with 1-D type tools or with injector design experience. The reviewer also wondered about the need for including cavitation damage in this simulation toolchain, being that the goal of the injector design is to not have cavitation damage. It seems that this is a useful tool to help get the injector design right, but it is not necessarily needed to predict the spray and combustion of damaged nozzles. Maybe there is a real need or use here that can be highlighted more clearly.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the project team showed that the collaboration and coordination with various other organizations were done well.

Reviewer 2:

The reviewer commented that a well-coordinated collaboration of ANL, Lawrence Livermore National Laboratory (LLNL), SNL, Converge, and university partners is combined with industrial partner involvement.

Reviewer 3:

The reviewer stated that there is very clear collaboration and coordination among the national laboratories, industry, academia, and CRADAs.

Reviewer 4:

The reviewer remarked that the collaboration part is great and had nothing to point out.

Reviewer 5:

The reviewer said that there is a fairly long list of collaborators over the years from other national laboratories to engine OEMs and software suppliers. The reviewer thought that it is essential to work with Converge to improve the models that will eventually be available to all OEMs that use the Converge software.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer remarked that the PI and the project team continue to improve models and develop new ones that are applicable to the industry. There is a long list of future barriers that can still be addressed and plans to make progress on all of them. Overall, it is a vast project, but the project team is making good progress in all areas.

Reviewer 2:

The reviewer commented that the goal is solid: link cavitation, erosion, combustion, and emissions. Specifically, the link to soot formation will be crucial.

Reviewer 3:

All the proposed research picks up on the current accomplishments and progress, and it was clear to the reviewer that it is subject to future funding. The reviewer encouraged the teams to orient toward off-road, marine, and rail with low GHG fuels, per the VTO's new funding statements.

Reviewer 4:

The reviewer noted that the ELSA model was developed more than 20 years ago, and it has been implemented in several commercial computational fluid dynamics (CFD) codes, including CONVERGE. An elaboration of the model development and improvement is needed (on Slide 15).

Reviewer 5:

Although further studies on injector nozzle cavitation and erosion seem necessary, the reviewer was not convinced that injector nozzle cavitation and erosion should be the most critical area of this project. From a heavy-duty engine maker point of view, spray-wall interaction, air-fuel mixing, and accurate prediction of NO_x-soot trade-off are far more important than the nozzle internal flow simulation or soot modeling.

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

Reviewer 1:

According to the reviewer the final goal is to be able to take the models developed and collaborate with Converge to incorporate them into their commercial software. If successful, the efforts from the DOE supporting the work will be well received via the industry.

Reviewer 2:

The reviewer found this project to be helpful for relevant industries to access advanced modeling tools and practices and utilize them for their engines with better emissions and engine efficiency, which should be relevant to DOE also.

Reviewer 3:

The reviewer commented that the project targets DOE barriers in spray fundamentals, aids advanced low-temperature combustion strategies, and contributes to soot modeling.

Reviewer 4:

The reviewer remarked that this supports increased understanding, physics modeling, and simulation of higher efficiency internal combustion engines (ICEs) for reduced fuel consumption and emissions.

Reviewer 5:

The reviewer indicated that the project supports the DOE objectives in a way to enable a predictive tool development for more durable and efficiency engine development.

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

Reviewer 1:

It seems sufficient by looking at the good progress in the key milestones, according to the reviewer.

Reviewer 2:

The reviewer commented that the team appears well supported to conduct the investigation.

Reviewer 3:

The funding looked sufficient to the reviewer.

Reviewer 4:

It was clear to the reviewer there are sufficient experimental capabilities and high-performance computing (HPC) resources. Having a CFD vendor tightly incorporated should really help the simulation development and project deliverables.

Reviewer 5:

The reviewer thought that there could be more funds allocated to this program. There are minimal funds to support the computer modeling, and the reviewer expected that a good portion of the overall funds are going toward the Erosion Spray Rig (which is important and recommends continuing to move forward). However, an additional modeler would speed up the overall results.

Presentation Number: ace166
Presentation Title: New Two-Cylinder Prototype Demonstration and Concept Design of a Next Generation Class 3-6 Opposed Piston Engine
Principal Investigator: Fabien Redon (Achates Power, Inc.)

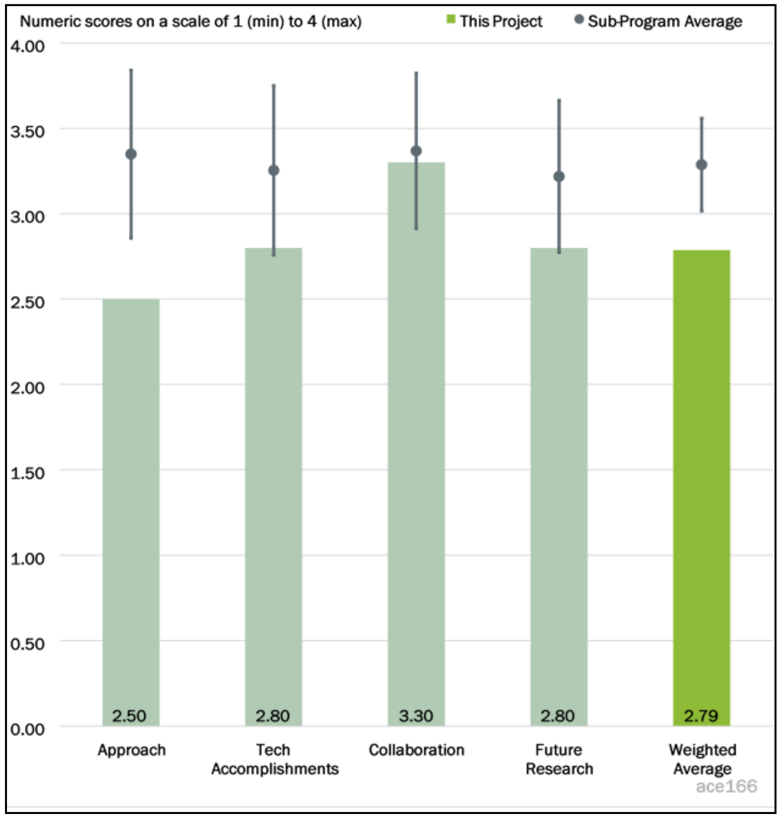

Figure 1-39 - Presentation Number: ace166 Presentation Title: New Two-Cylinder Prototype Demonstration and Concept Design of a Next Generation Class 3-6 Opposed Piston Engine Principal Investigator: Fabien Redon (Achates Power, Inc.)

Presenter

Fabien Redon, Achates Power, Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

60% of reviewers felt that the project was relevant to current DOE objectives, 40% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 program plan is comprehensive and that the project benefits from Achates experience of having had a number of DOE-funded projects.

Reviewer 2:

The approach is well matched to the specific barriers noted in the presentation. However, the reviewer indicated that specific barriers related to the DOE VTO mission are not clearly linked to the work or the approach. The project design and teaming are well matched for the project objectives. It could be made clearer how this effort builds on previous work and what lessons and improvement are being applied here for this specific application.

Reviewer 3:

According to the reviewer, the project approach does not adequately address the challenges of meeting ultra-low emission requirements. Efficiency gains made in this project will not be transferable to the automotive commercial sector unless emissions are adequately addressed, and there is insufficient emphasis or concern for emissions as this project is currently constructed. If the approach is to move this engine design toward meeting efficiency goals in this project and then meeting emission requirements in some future effort, then that should be stated in the presentation.

Reviewer 4:

The overall approach of specifying engine requirements, simulation, testing was sensible to the reviewer. A key flaw is targeting high-level barriers (challenges) of conventional diesel engines whereas the more appropriate barriers would be the persisting technical barriers facing this particular engine architecture. The specific approach to the important, relevant barriers is not really complete. It would be constructive to show the technical issues that have been resolved for the Achates design over 17 years of research and show the few issues that still need more work.

The reviewer indicated that the target of 10% efficiency gain over standard engines is too conservative for the relatively high risk of an unconventional engine. The demonstration of emissions target is unclear whether by hardware, vehicle, or simulation. This question came up in question and answer (Q&A) and was not clearly answered.

Reviewer 5:

The reviewer stated that there is significant overlap with other federally funded projects. The market for this engine design is decreasing as states are requiring that zero emission Class 3-6 vehicles be purchased in the next 10-15 years. Larger (Class 8) engine research should be completed prior to starting more research in this area. A 10% fuel economy increase target is low compared to risks associated with this project.

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 project is in its early days, but good progress has been made to date.

Reviewer 2:

The reviewer indicated that good progress has been made early into the project. The milestones on system profile and updating the CFD model and 1-D model for opposed piston architecture are in line with ensuring progress.

Reviewer 3:

Although early in the project, the reviewer stated that the effort made to date is in accordance with the statement of project objectives (SOPO) and indicates that the project is just about where it should be now.

Reviewer 4:

This is a new project the reviewer remarked so accomplishments are in early stages for this specific application of a two-stroke engine. The project team has installed a test engine at Clemson. Simulation and design of a two-cylinder engine is in progress.

Reviewer 5:

The reviewer pointed out that no hardware progress has been accomplished (was not a milestone, but for this amount of funding, some brass board testing should have been started based on the Class 8 research). Limited background research and modeling (which should have been accomplished prior to the project) was accomplished in year 1.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Great teaming and application of partner strengths to overall goals, according to the reviewer.

Reviewer 2:

The reviewer commented that the overall project team is strengthened by the participation of a major engine manufacturer. The university partners are traditionally strong in engine research. The reviewer noted capabilities in thermal barriers as well.

Reviewer 3:

The reviewer asserted that coordination with other project members is adequate for this project to achieve the stated goals and be successful.

Reviewer 4:

The reviewer stated that there are well-defined roles for the partners. although Isuzu's engine design capability. Is being underutilized. There is good use of the university partners' supporting modeling efforts.

Reviewer 5:

It is too early to tell if the collaboration and coordination work. The comment about Clemson possibly not being able to perform the model predictive control (MPC) work was concerning to the reviewer. This would allow the test matrix to be expanded and optimized; the absence of this aspect of the work will increase the testing required at reduced overall benefit.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented that the team understands the complexities and difficulties of engine development and has laid out a comprehensive SOPO.

Reviewer 2:

The reviewer found the project has a very good future research plan aligned well to overall goals.

Reviewer 3:

The reviewer asked that the research to achieve a commercial-ready technology should be described. The low-emissions achievement should be clarified as either a vehicle demonstration or partly done by simulation. This section of the project and presentation needs improvement to address these issues.

Reviewer 4:

The reviewer remarked that this project does not give adequate weight to the difficultly that will most likely be encountered in meeting emission requirements, even though engine-out data rather than tailpipe-out are what are being measured. More emphasis needs to be directed toward meeting ultra-low emissions because this is a major challenge for all engine development efforts and particularly for two-stroke engines. The PI for this project does not seem to recognize the challenge that lies ahead in terms of meeting the emission standards set for this project.

Reviewer 5:

The reviewer suggested using funding for other purposes, such as Class 8 research and engine development, demonstration, and deployment before modeling and developing new engine designs for alternative vehicle applications. Alternative fuels should be incorporated into the Class 8 testing scheme to improve engine-out emissions (question was asked about this topic but was never answered).

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

Reviewer 1:

According to the reviewer, the investigation of improvements to IC engine efficiency and reduced emissions is still an essential part of automotive development. The use of low-carbon or zero-carbon fuels in a highly efficient engine architecture is another area worth pursuing.

Reviewer 2:

The reviewer proposed that investigating and developing an alternative engine design to the commercially available diesel engine is needed for increased diversification of the DOE research portfolio. This project meets that need.

Reviewer 3:

The reviewer said that this project does support the overall DOE goals of improving efficiency and reducing emissions in the MD and heavy-duty (HD) vehicle sector using advanced engine technologies. The project uses advanced tools, such as CFD, machine learning, and lower-order models, to accelerate the implementation of the designs. The project could be better linked to published DOE and industry partnership goals, such as noted in the 21 Century Truck Partnership.

Reviewer 4:

The reviewer found that relevance is a weak spot for this project. The projected benefits of this engine (10%) for DOE's mission are not large enough to justify investment at this time of emerging electric vehicles and continuing improvements being seen in "conventional" ICE vehicles that are moving the needle much more than 10%. If the engine showed a vastly superior applicability of low-carbon fuels, its relevance could be re-argued. Similarly, there are already efforts to exploit hybrid systems with this engine. The emissions from the engine are only as good as conventional engines, apparently not targeting lower levels.

Reviewer 5:

No, this project does not support the DOE objectives toward zero-emission vehicle development.

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 engine development is very expensive, but Achates has developed a number of variants, which ensures that they know what the true costs are or will be.

Reviewer 2:

This is a large project with significant goals. The resources seemed to the reviewer to be well matched to deliver in a timely fashion.

Reviewer 3:

Resources for this effort are sufficient; however, it seems that Achates should be providing greater cost share than they are at present. Achates has been developing this engine for quite some time and the opposed piston configuration is a known quantity so the reviewer proposed that the usual 50% cost share would be more appropriate.

Reviewer 4:

Many parts of government have made investments in this engine architecture and company, and some are still in progress. The cost share by industry for this project is lower than the typical 50% for DOE industry product development programs. The presenter noted various development programs ongoing for 17 years since

Achates was formed. The engine may be well suited for military or other applications. The resources are okay for the tasks being pursued, but the reviewer questioned the overall relevance and benefits of the project.

Reviewer 5:

The reviewer indicated that this project overlaps with other federally funded research on a slightly larger engine design. That work should be completed and assessed prior to investing more funds into this engine design.

Presentation Number: ace167
Presentation Title: Spray/Flow Interaction in Engines
Principal Investigator: Roberto Torelli (Argonne National Laboratory)

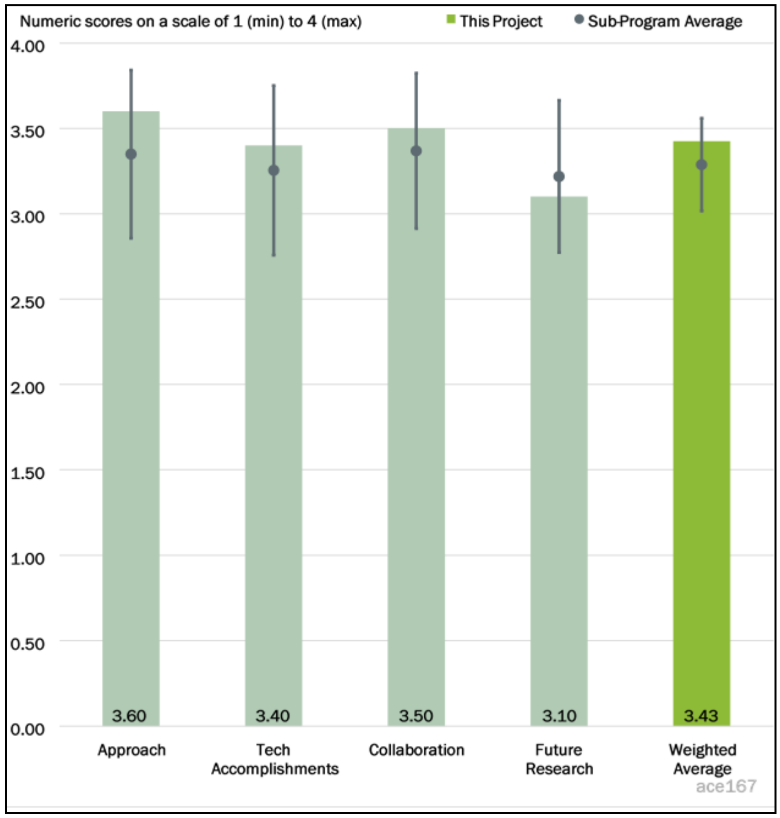

Figure 1-40 - Presentation Number: ace167 Presentation Title: Spray/Flow Interaction in Engines Principal Investigator: Roberto Torelli (Argonne National Laboratory)

Presenter

Roberto Torelli, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 project investigates free sprays and spray-wall interaction along with mixture formation for high-efficiency combustion regimes. Spray modeling is something for which improvements need to be done on a continuous basis, and this effort achieves that. There is very high quality CFD work to match experimental observations.

Reviewer 2:

The project is focusing on both free spray and wall impinging jet through numeral and experiment work. The reviewer noted that very informative data from the experiments are fed to CFD so that the spray wall interaction model can be improved.

Reviewer 3:

The reviewer pronounced the connections between the various modeling-experimental approaches to be excellent.

Reviewer 4:

It looked to the reviewer like the approach is great.

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 asserted that the Slide 3 results are excellent. While the fundamental understanding behind GDI cold-start issues is paramount, the practical solutions are also incredibly helpful. The various experimental-modeling connections are excellent.

Reviewer 2:

The reviewer made several observations: multi-hole spray collapse in engine conditions seems to be very useful information, flash-boiling breakup and one-way coupling of injection are proven to be important, the necessity of setting up spray-cone included-angle seems to be limited in CFD modeling, and a new spray-wall interaction model has been made available to other users.

Reviewer 3:

The reviewer found the project to be a very nice combination work of experiment and simulation while asking if the new spray-wall interaction (SWI) model is more predictive than "postdictive,", negating calibration needs. The reviewer commented that it looks like the new SWI model needs improvement on the side-wall side.

Reviewer 4:

According to the reviewer, technical accomplishments are in line with what was proposed. Perhaps something lacking in the effort is the droplet-size quantification and comparison with some fundamental experiments (e.g., phase Doppler particle analyzer [PDPA] or other) along with qualitative assessment of the spray. The droplet-size measurement is important for equivalence ratio distribution as well as combustion and emissions formation, of course. Wall film development and some validation with experiments will also be beneficial for understanding soot formation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

From the three spray talks, the collaboration appeared excellent to the reviewer.

Reviewer 2:

Again, the collaboration looked excellent to the reviewer.

Reviewer 3:

The reviewer observed good collaboration and stated that this is an effort applicable to pretty much all advanced combustion CFD work.

Reviewer 4:

The reviewer said that collaborations with project partners among national laboratories seem well coordinated. For spray modeling, more involvement with industry would be helpful to hear their needs also, maybe first through DOE Advanced Engine Combustion (AEC) members, either CFD software vendors, or manufacturers.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the research appears to be fine. It sounds like Eco-boost engine experiments will be pursued. These engines use a side-mounted injector (spraying orthogonally to the cylinder axis). A comparison of cylinder axial injection versus side injection would be helpful.

Reviewer 2:

This reviewer remarked that fuel film formation on the cold wall is difficult to simulate accurately, let alone for free spray before reaching to the wall. The reviewer suggested that some other factor like wall roughness can be considered in simulations.

Reviewer 3:

-It looked to the reviewer like the spray-wall (SW) model needs some fundamental improvement than trying more validation cases. The reviewer did not see a clear benefit of implementing the Huh-Gosman model to CONVERGE. The reviewer wanted to know what the purpose of it is in the context of the project, what is new with the CHT model, and what is it going to bring into the project. Overall, the return seems a bit diminishing.

Reviewer 4:

If possible, the reviewer suggested that a wide variety of validation should be done compared to experiments. Droplet-size distribution may be important for predicting mixture formation (due by September 2021).

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

Reviewer 1:

The reviewer found that this project supports the PACE DOE objectives in understanding spray mixing behavior in engine and overcoming technical barriers.

Reviewer 2:

According to the reviewer, the project supports the DOE objectives. It will contribute to understanding the spray physics better and improve prediction capabilities of simulation tools.

Reviewer 3:

The reviewer asserted that this is exactly the kind of work national laboratories should be conducting and feeding to industry. There is perfect alignment with DOE goals.

Reviewer 4:

It would have been nice to see emissions results from the engine experiments in order to get a sense of the baseline as well as other approaches applied. The reviewer indicated that connecting back (even briefly) to the end goal would be useful.

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

Reviewer 1:

The reviewer pronounced the resources as excellent and appearing to be fine.

Reviewer 2:

The resources looked sufficient to the reviewer.

Reviewer 3:

The reviewer deemed the resources as sufficient.

Reviewer 4:

The reviewer observed that there are many tasks to be done in FY 2021 and FY 2022, but the resources seem just right to move along and achieve the milestones in time.

Presentation Number: ace168
Presentation Title: Soot Modeling and Experiments
Principal Investigator: Julien Manin (Sandia National Laboratories)

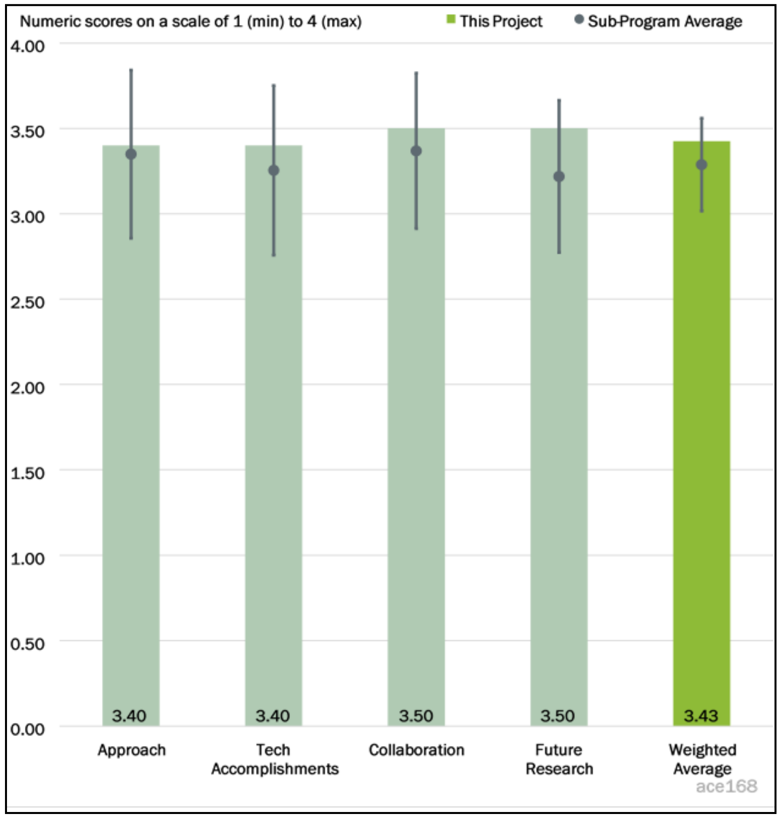

Figure 1-41 - Presentation Number: ace168 Presentation Title: Soot Modeling and Experiments Principal Investigator: Julien Manin (Sandia National Laboratories)

Presenter

Julien Manin, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

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 approach of this program is very well designed. The more fundamental chemistry development is happening on the right levels and is well connected, leading to computationally efficient soot models for industry use. The experiments are tied in with the modeling effort, and it looked to the reviewer like future work will have more high-fidelity simulation to see if the chemical models are matching the experiments. This is going to be an important step, and so it will be good to see those results next year. It was unclear to the reviewer if the simulations will be able to capture the wall-impingement work; it would be good to clarify that. Otherwise, the program structure and approach are appropriate and yielding very interesting and useful results.

Reviewer 2:

Soot modeling is one of the most difficult tasks in any engine modeling area. According to the reviewer, the project team seems to understand the issues and tasks to resolve to develop a reliable soot model for engine cold start.

Reviewer 3:

The reviewer asserted that the approach is excellent as good models need to first be in place.

Reviewer 4:

The reviewer called the approach excellent, based on the use of the multiple types of experimental data sources feeding the high-fidelity simulation work that then will be distilled to the CFD-ready deliverables. Soot is an incredibly challenging topic regarding accuracy. Major Outcome 8 of PACE has a less than 20% relative error on cold-start emissions, which includes soot. The reviewer asked the project team to think about how to tie this ACE168 to the less than 20% error at the current status. Where is the team relative to this less than 20% error today?

Reviewer 5:

This reviewer commented that organizing a soot working group and focusing on the cold start is good. The entire period while the engine is below operating temperature is critical for soot research, not just the 20-30 seconds of catalyst heating, which is critical for HC, NO_x, and CO.

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 called all the technical accomplishments of the many different aspects of the program excellent. There are five that stand out at this point as particularly high impact. First, the pyrolyzing spray experiments are really interesting, and the combined diagnostics provide important information on PAH and soot together, which will be critical for comparison to simulation. Second, the improved PAH chemistry is really nicely done, and it is good to see that one of the outcomes of this will be publication of the updated mechanism online. Third, the initial comparison of the new chemistry in CONVERGE with experiments is promising; continuing to benchmark these improvements will be important. The 0-D model is quite clever, and it is nice to see the lab working with early-career academics on this effort. Finally, the wall-film experiments are yielding very interesting results. It might be good to coordinate with the experiments presented by Lyle Pickett on their wall-impingement studies. It is also encouraging to see that despite the challenges, the PIs are working toward understanding these processes in an engine experiment.

Reviewer 2:

The reviewer asserted that the accomplishments and progress are excellent, based on four of seven deliverables being complete and three of seven are on track. The cold-start engine experiments seem to be very valuable to highlight the importance of the thermal state of the engine regarding the sooting similarity between the RD5-87 and PACE-20 fuels. Similarly, the spray vessel pyrolysis experiments help to corroborate the surrogate fuel similarities for sooting.

To achieve the goals of the PACE Output 8, the kinetics and simulation work is key, and it looks to be making good progress. The reduced PAH mechanism looks to be validated sufficiently, but a reference-reduced PAH mechanism would be nice to compare. The Reynolds-averaged Navier-Stokes (RANS) CFD of the pyrolysis is excellent in that it clearly illuminates the gap and where to focus efforts on the kinetics leading to soot formation. This seems to be critical area, and it looks like the team is making very good progress on it.

Reviewer 3:

The reviewer said there was excellent progress.

Reviewer 4:

The reviewer suggested that the project team please seek to connect the current work to the end goal and how the current work will ultimately allow for cleaning GDI cold start from the particulate perspective.

Reviewer 5:

The reviewer said that the team identified soot sources during engine cold start, but no explanation was given on the finding, which could be explained through CFD with currently available soot models or other parameters. Zero-dimensional (0-D) simulation of soot model seems to be a good approach for model parameter studies. Transitions from polycyclic aromatic hydrocarbons (PAHs) to soot were identified from wall-film experiments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Between the alignment to PACE and the involvement of SNL, LLNL, ANL, ORNL, and multiple universities, the reviewer remarked that this project demonstrates excellent collaboration.

Reviewer 2:

By definition, PACE has drastically improved collaboration across labs and with industry. The reviewer encouraged the project team to keep it up.

Reviewer 3:

The reviewer stated that collaboration was excellent.

Reviewer 4:

So far, there has been good collaboration across the different aspects of the project. It would be nice to see tighter integration with more CONVERGE simulations of the experimental configuration now that some of the new models have been developed and tested against simpler target flames. It looked to the reviewer like this is in the plan, which is good. There is also good collaboration with universities and other researchers through the Engine Combustion Network (ECN) and the International Energy Agency (IEA) working groups.

Reviewer 5:

The reviewer stated that the project team showed active collaboration with many universities and national laboratories. No interaction with industry was mentioned, but it could be done with AEC members.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer affirmed that the future research plan put forth on Slide 18 has clear and sufficient detail in six areas. It can be logically seen that these are the right next steps toward the goal of soot understanding, soot model development, and delivery.

Reviewer 2:

The reviewer encouraged the project team to continue to pursue experimentation and simulation to achieve predictability.

Reviewer 3:

The reviewer wondered how the models will perform during the expansion stroke as soot oxidation is likely to continue through engine expansion after combustion. This is important in diesels, so the reviewer was curious if that was also equally important in GDI during cold start.

Reviewer 4:

All the future paths for the research looked really good. As the reviewer had mentioned above, it would be interesting to see some simulation of the wall-wetting work, since this was identified as a particular problem at cold start. Otherwise, it is a good lineup for the next year. It would be helpful if the PIs included target dates for the tasks or a timeline.

Reviewer 5:

There were a couple of challenges and barriers identified for each of five different areas related to soot modeling and experiments. Each PI laid out items for further research, which seem quite reasonable. Soot formation can be a main source of soot during cold-start engine operation, so it is right to focus on it. However, the reviewer noted that how to suppress soot formation and accelerate soot oxidation seems to be missing in the whole picture of PACE.

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

Reviewer 1:

The reviewer commented that this project is an important part of the DOE PACE objectives to minimize engine-out and vehicle tailpipe emissions.

Reviewer 2:

The reviewer responded affirmatively and said that this project is clearly aligned with the DOE’s PACE consortium and Major Output 8.

Reviewer 3:

Improved prediction and reduction of soot is critical for cost-effective ICE applications, according to the reviewer.

Reviewer 4:

The reviewer commented that this project is highly relevant to the goals of PACE and hence the DOE objectives. It also integrates well with several other DOE-supported initiatives, like the ECN, which support better understanding and modeling of sprays, combustion, and emissions.

Reviewer 5:

The reviewer found the project to be very relevant to the GDI cold-start challenge, but only wondered about how the newer port fuel-injected (PFI)-GDI approaches may help the situation.

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

Reviewer 1:

The resources looked sufficient to the reviewer as all five PIs are involved actively, and research has progressed fine.

Reviewer 2:

Resources appeared fine to the reviewer.

Reviewer 3:

The resources seemed sufficient to the reviewer, and the PIs are executing the tasks in a timely manner.

Reviewer 4:

The reviewer expressed concern over FY 2022 spending cuts and their impact on this relevant and needed research.

Reviewer 5:

The experimental resources and computation resources seem to be in place. However, the reviewer did not understand how the new VTO budget, with the 57% reduction in Engine & Fuels funding, will or will not impact the PACE projects. Clearly, if it does, this project has insufficient funding resources.

Presentation Number: ace169
Presentation Title: Greatly Reduced Vehicle Platinum Group Metals (PGM) Contant Using Engineered, Highly Dispersed Precious Metal Catalysts
Principal Investigator: Yong Wang (Washington State University)

Presenter

Yong Wang, Washington State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

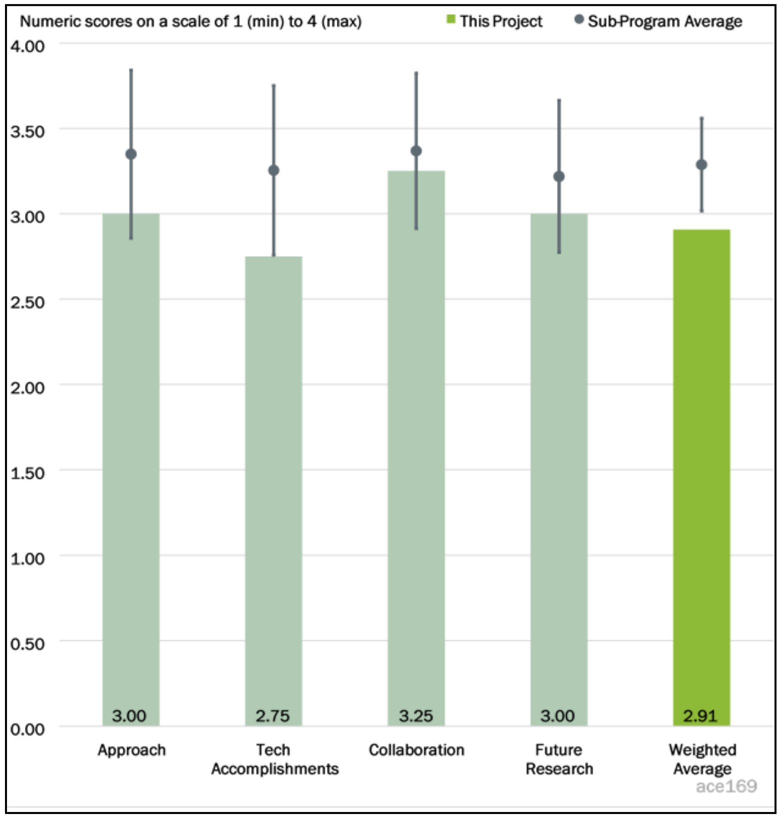

Figure 1-42 - Presentation Number: ace169 Presentation Title: Greatly Reduced Vehicle Platinum Group Metals (PGM) Contant Using Engineered, Highly Dispersed Precious Metal Catalysts Principal Investigator: Yong Wang (Washington State University)

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 is a very well thought out project, and the reviewer appreciated the matrix of catalyst combinations that will be tested. Also, it is good to see hydrothermal aging and sulfur resistance included in the scope. It is not clear if the final optimized catalysts will be tested on a vehicle (the goal is super ultra-low emission vehicle [SULEV20/30] compliance), but that would be good to include if possible. The reviewer suggested it will be useful to identify any barriers for commercialization as early as possible to either address them here or serve as motivation for future research.

Reviewer 2:

The reviewer opined that the approach of using SAC to reduce PGM content (if successful) would go a long way to overcoming the barrier related to sustainability and cost. However, no further information was provided on the approach other than to say researchers will use the U.S. DRIVE protocol to see if the SACs work, yet the current catalyst data presented by the researchers did not use conditions listed in the protocol. In order to understand and compare data from the proposed SAC with currently available catalysts, it is imperative that the protocol conditions be used to support positive SAC results.

Reviewer 3:

Researchers indicated several times that SACs were going to be the focus of their advanced materials that were synthesized using atom trapping. This approach has been clearly described during the review and in the literature. However, the literature has also indicated that the SAC materials do not necessarily result in the highest reactivity, especially for hydrocarbons. In fact, it is clusters that have better reactivity. The reviewer thought that it will be important for the researchers to clarify whether it is SAC or stable clusters as the project moves forward. If less than approximately 1nanometer(nm), all of the metals will be exposed to the surface, and this may be the true goal of the project. It seems that the tailored oxygen storage capacity (OSC) phase will be the most important aspect of the study, and the reviewer was looking forward to more discussion on that in the coming years.

The reviewer was a little concerned that the two projects have different starting points for the PGM content, as the percentage improvement will be very different.

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 progress made so far is promising.

Reviewer 2:

Relevant simulated exhaust compositions were not used to evaluate the baseline catalyst presented. The baseline catalyst will need to be retested with the U.S. DRIVE protocol conditions in order to validate future results of new SACs. It was unclear to the reviewer if the researchers understand the parameters provided in the U.S. DRIVE protocol that was mentioned in the approach; during Q&A, the project team claimed to have followed the protocol, yet its figures clearly indicate different conditions. Additionally, the current gas hourly space velocity (GHSV) and gas compositions listed as being used are not relevant to stoichiometric gasoline exhaust and thus, do not provide useful catalyst information related to the TWC application.

Reviewer 3:

Having some data at this point was nice to see, and the team deserves credit for showing progress already. However, it was troubling to the reviewer that the evaluations were not performed under stoichiometric conditions and not while flowing all the criteria pollutants at the same time, which of course is the definition of TWC. If the researchers are looking for one material to do CO and NO, while another material does HC conversion, then it should be stated explicitly. In the end, there was a lot of confusion as to what the results indicated. Additionally, it is not clear why hydrothermal aging (HTA) was performed in air rather than lean-rich cycling or at least under neutral conditions. It almost seemed like these results were not directly intended for this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that this is an excellent team with a track record of fundamental emissions control research and characterization and good industry partners.

Reviewer 2:

It looked like a well-coordinated effort to the reviewer.

Reviewer 3:

The project team includes a diverse team that crosses all research sectors. Tasks seemed appropriate to the reviewer for assigned partners’ capabilities.

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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the proposed future research is good, especially since it lists experimental conditions that are more relevant than the initial ones shown in the results section. It will be good to see the approach proposed scaled up to larger sizes for washcoating.

Reviewer 2:

The reviewer asserted that it was good to see sulfur tolerance in the plan. It would be worth doing at least a couple of experiments at varying space velocities to examine any impact of pore diffusion effects.

While aiming to show similar conversion with low PGM, it would be useful to also show how much improvement in conversion could be achieved using similar PGM levels with the SACs (or if there is an upper bound on the loadings achievable).

Reviewer 3:

The only details given were to state that new SAC would be tested according to protocol and scale up. The lack of detail related to future work made it difficult for the reviewer to evaluate; future work does not include decision points or possible barriers. The lack of this information makes it difficult to discern if the project team will be making new catalysts or just going to retest catalysts presented under appropriate exhaust conditions.

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

Reviewer 1:

The reviewer emphasized that reducing PGM content is very critical, given the high prices. Also, this will help with improved conversion of pollutants.

Reviewer 2:

The reviewer noted that the target of showing that SACs are more active than state-of -the-art, commercial TWCs at relevant temperatures would support DOE's objective of reducing PGM use.

Reviewer 3:

The reviewer said that PGM research is clearly important due to the expected deficit in supply in the near future. This research has the potential to alleviant this in a short time period.

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

Reviewer 1:

The resources are sufficient to do the intended tasks considering the increased cost of on-vehicle testing that will occur in the later stages, according to the reviewer.

Reviewer 2:

Resources look sufficient. It was not clear to the reviewer whether atomic modeling is included to help facilitate catalyst development— maybe it has already been done in the past— but it is worth clarifying the plans for this project.

Reviewer 3:

DOE resources are sufficient for this project, although the reviewer opined that it would have been nice to see additional funding coming from industry to support this research.

Acronyms and Abbreviations

°C	Degrees Celsius
0-D	Zero-dimensional
1-D	One-dimensional
2-D	Two-dimensional
3-D	Three-dimensional
3PL	Third-party logistics
A/F	Air/fuel
ACE	Advanced Combustion Engines
ACEC	Advanced Combustion and Emissions Control
AEC	Advanced Engine Combustion
Ag	Silver
AI	Artificial intelligence
AMOX	Ammonia oxidation
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ASC	Ammonia slip catalyst
BEA	Zeolite beta
BES	Basic Energy Sciences
BEV	Battery-electric vehicle
BP	Budget Period
BTE	Brake thermal efficiency
CA10	Crank angle at 10% mass fraction burned
CAFE	Corporate Average Fuel Economy
cc	Close coupled
CCV	Cycle-to-cycle variation
Ce	Cerium
CFD	Computational fluid dynamics
CH_4	Methane
CHA	Chabazite
CHT	Conjugate heat transfer
CI	Compression-ignition

CLEERS	Crosscut Lean Exhaust Emissions Reduction Simulations
CIERA	Cavitation-induced erosion risk assessment
CO	Carbon monoxide
Co	Cobalt
CO_2	Carbon dioxide
COVID-19	Coronavirus disease 2019
COTS	Commercial-off-the-shelf
CR	Compression ratio
CRADA	Cooperative research and development agreement
CS	Cold start
CS	Cooled spray
CT	Computerized tomography
Cu	Copper
CUC	Clean up catalyst
DFI	Ducted fuel injection
DFP	Diesel particulate filter
DI	Direct injection
DMTV	Discharge molecular tagging velocimetry
DNS	Direct numerical simulation
DOC	Diesel oxidation catalyst
DOC-F	Combined diesel oxidation catalyst and diesel particulate filter
DOE	U.S. Department of Energy
DPF	Diesel particulate filter
E10	10% ethanol, 90% gasoline blend
EAT	Exhaust aftertreatment
ECFM	Extended coherent flame model
ECN	Engine Combustion Network
EERE	Office of Energy Efficiency and Renewable Energy
EGR	Exhaust gas recirculation
EHC	Electrically heated catalyst
ELSA	Euler-Lagrange spray atomization
EMSL	Environmental Molecular Sciences Laboratory

EPA	U.S. Environmental Protection Agency
EPR	Electron paramagnetic resonance spectroscopy
Fe	Iron
FTE	Freight-ton efficiency
FTIR	Fourier-transform infrared spectroscopy
FTP	Federal Test Procedure
FY	Fiscal Year
g/hp-hr	Gram per horsepower-hour
GCI	Gasoline compression ignition
GDI	Gasoline direct injection
GHG	Greenhouse gas
GHSV	Gas hourly space velocity
GM	General Motors
GPCF	Gallon per cubic foot
GPF	Gasoline particulate filter
GPR	Gaussian process regression
GPS	Global positioning system
GVWR	Gross vehicle weight rating
H_2	Hydrogen
H_2O	Water
HC	Hydrocarbon
HCT	Hydrocarbon trap
HD	Heavy-duty
HFET	Highway Fuel Economy Test
HFS	High fuel stratification
HIL	Hardware-in-the-loop
HPC	High performance computing
HTA	Hydrothermally aged
HVAC	Heating, ventilation, and air conditioning
IC	Internal combustion
ICE	Internal combustion engine
ITE	Indicated thermal efficiency

L	Liter
lb	Pound
LD	Light-duty
LES	Large eddy simulation
LIDAR	Light detection and ranging
LLNL	Lawrence Livermore National Laboratory
LSPI	Low-speed pre-ignition
LTAT	Low-temperature aftertreatment
LTC	Low-temperature combustion
LVF	Liquid volume fraction
MCCI	Mixing-controlled compression ignition
MCE	Multi-cylinder engine
MD	Medium-duty
MER	Molar expansion ratio
MIT	Massachusetts Institute of Technology
ML	Machine learning
Mn	Manganese
MnCe	Manganese cerium
MOU	Memorandum of Understanding
MPC	Model predictive control
MPR	Multi-pressure rail
MY	Model Year
N_2O	Nitrous oxide
nm	Nanometer
NM	Non-methane
NMHC	Non-methane hydrocarbon
NO	Nitric oxide (nitrogen monoxide)
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NREL	National Renewable Energy Laboratory
NTC	Negative temperature coefficient
NYCC	New York City Cycle

OEM	Original equipment manufacturer
OHC	Oxidation half cycles
ORNL	Oak Ridge National Laboratory
OSC	Oxygen storage capacity/component
P	Pressure
PACE	Partnership for Advanced Combustion Engines
PAH	Polycyclic aromatic hydrocarbon
PC	Pre-chamber
PCI	Precision Combustion Inc.
PCP	Peak cylinder pressure
Pd	Palladium
PDPA	Phase Doppler particle analyzer
PFI	Port fuel injection
PFS	Partial fuel stratification
PGM	Platinum group metals
PI	Principal Investigator
PIV	Particle image velocimetry
PM	Particulate matter
PNA	Polynuclear aromatics
PNNL	Pacific Northwest National Laboratory
ppm	Parts per million
Pt	Platinum
Q&A	Question and answer
R&D	Research and development
RANS	Reynolds-averaged Navier-Stokes
Rb	Rubidium
RCM	Rapid compression machine
RD5-87	Research-grade regular E10 gasoline
RDD&D	Research, development, deployment, and demonstration
Rh	Rhodium
RHC	Reduction half cycle
rpm	Revolutions per minute

Ru	Ruthenium
S	Flame speed
S	Sulfur
SAC	Single-atom catalyst (catalysis)
SAE	Society of Automotive Engineers
SCE	Single-cylinder engine
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SI	Spark ignition
SNL	Sandia National Laboratories
SNS	Spallation Neutron Source
SOA	State of the art
SOPO	Statement of project objectives
Spaci-MS	Spatially resolved capillary inlet - mass spectroscopy
SPI	Stochastic pre-ignition
SULEV	Super Ultra-Low Emissions Vehicle
SW	Spray wall
SWI	Spray-wall interaction
SwRI	Southwest Research Institute
t	Time
TCC-III	Transparent combustion chamber
TCO	Total cost of ownership
TPD	Temperature programmed desorption
TPR	Temperature programmed reduction
TPRF	Toluene primary reference fuel
TRL	Technology Readiness Level
TWC	Three-way catalyst
UDF	Undefined user files
UFPV	Unsteady flamelet progress variable
UH	University of Houston
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability

UVA	University of Virginia
UW-Madison	University of Wisconsin at Madison
V	Volt
VMT	Vehicle-miles traveled
VOF	Volume of fluid
VTO	Vehicle Technologies Office
WHR	Waste heat recovery
WSR-MZ	Well-stirred reactor multi-zone
wt.%	Weight percent
Zero-RK	Zero-Order Reaction Kinetics
Zr	Zirconium
ZSM-5	Zeolite Sacony Mobil5