7. Materials Technologies: Propulsion Materials

Advanced materials are essential for boosting the fuel economy of modern automobiles while maintaining safety and performance.

Propulsion materials enable higher efficiencies in propulsion systems of all types. For example, many combustion engine components require advanced propulsion materials so they can withstand the high pressures and temperatures of high-efficiency combustion regimes. Similarly, novel propulsion materials may be able to replace the current expensive materials in electric motors and drivetrain components, thus lowering the cost of electric-drive vehicles.

Using lightweight components and high-efficiency engines enabled by advanced materials in one quarter of the U.S. fleet could save more than 5 billion gallons of fuel annually by 2030.

The Vehicle Technologies Office (VTO) collaborates with industry to improve materials that will increase vehicle efficiency while meeting consumer and industry expectations. It does this through multiple approaches, including working closely with other VTO technology areas to identify and meet requirements for materials needed to develop cost-effective, highly efficient, and environmentally friendly next-generation heavy and light duty power-trains.

The major research and development (R&D) goal for Propulsion Materials is:

- Develop high performance cost-effective materials that solve key challenges that currently limit the performance of propulsion systems (high-efficiency engines and electric drive, and compatibility with alternative fuels).

Subprogram Feedback

The U.S. Department of Energy (DOE) welcomed optional feedback on the overall technical subprogram areas presented during the 2013 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

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

Question 1: Was the subprogram area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year?

Question 2: Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

Question 3: Does the subprogram area appear to be focused, well-managed, and effective in addressing the DOE Vehicle Technologies Office's needs?

Question 4: Other Comments.

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

Subprogram Overview Comments: Jerry Gibbs (U.S. Department of Energy) – pm000

Question 1: Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year?

Reviewer 1:
The reviewer stated yes, yes, and yes, that all three questions were addressed. This reviewer added that this introductory presentation was perhaps the most solidly analytical overview of the materials challenges presented by the need to increase the fuel economy of vehicle engines. This reviewer emphatically noted a great job.

Reviewer 2:
The reviewer indicated that this sub-program was one of the most diverse, because it supported all of the other sub-programs. This was a good high-level overview.

Reviewer 3:
The reviewer felt that the presentation was informative.

Reviewer 4:
The reviewer remarked that the coverage of the sub-program was good. In general, the progress was well presented, though in some cases the challenges were not well defined. It would have been an improvement for project Gantt charts to be provided in a standard format.

Reviewer 5:
The reviewer commented that the program covered a wide range, including alternative powertrain materials. However, this reviewer noted fewer projects on the hybrid systems, and added that the new solicitations were on conventional internal combustion engine (ICE) powertrains. Hopefully in the future, the focus would be on materials for hybrid systems. As more and more vehicles were being moved to hybrid systems, materials needed to be developed for large-scale manufacturing and reliability.

Question 2: Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

Reviewer 1:
The reviewer pointed out that the plans for addressing issues and challenges were clearly identified and the approaches were laid out to address the materials limitation issues.

Reviewer 2:
The reviewer observed a good job describing the major challenges (increasing exhaust temperatures, timescales for implementing new technologies, etc.) as well as how the sub-program was handling them.

Reviewer 3:
The reviewer said that no gaps were noticed.

Reviewer 4:
The reviewer mentioned that the issues seemed to cover a wide range of applications and barriers, but that the program was handling focused research in a large number of different areas.

Question 3: Does the sub-program area appear to be focused, well-managed, and effective in addressing the DOE Vehicle Technologies Program's needs?

Reviewer 1:
The reviewer mentioned that this sub-program was focused on an enabling technology for the overall DOE VTO. It was nice to see that the relations with this program were clearly identified, and the sub-program was well focused.

Reviewer 2:

The reviewer asserted that this sub-program was an enabler for the rest of the VTO and, as such, appeared to be very closely plugged into VTO's overall needs.

Reviewer 3:

The reviewer affirmed that it appeared to be focused and well managed. This reviewer added that the diversity in programs seemed rather limited to a select number of groups.

Reviewer 4:

According to this reviewer, this sub-program was very well focused, well managed, and effective in addressing the DOE VTO needs. Unfortunately, resources (funding) were clearly inadequate to cover the needs identified or to accelerate development of new material compositions in a timely fashion. This reviewer added that it usually took about 10 years to develop a new alloy composition and get it qualified for specific usages. Without adequate resources, this timeframe could be delayed by as much as four years.

Question 4: Other Comments

Reviewer 1:

The reviewer expressed that Gibbs had done a great job as session chair. He managed time well and made sure that all of the questions were answered. The presentations were grouped in a logical order, and this was a very enjoyable session.

Reviewer 2:

The reviewer suggested that it might be useful to see the full portfolio of projects, and added that every year only a portion of the project portfolio was being reviewed.

Reviewer 3:

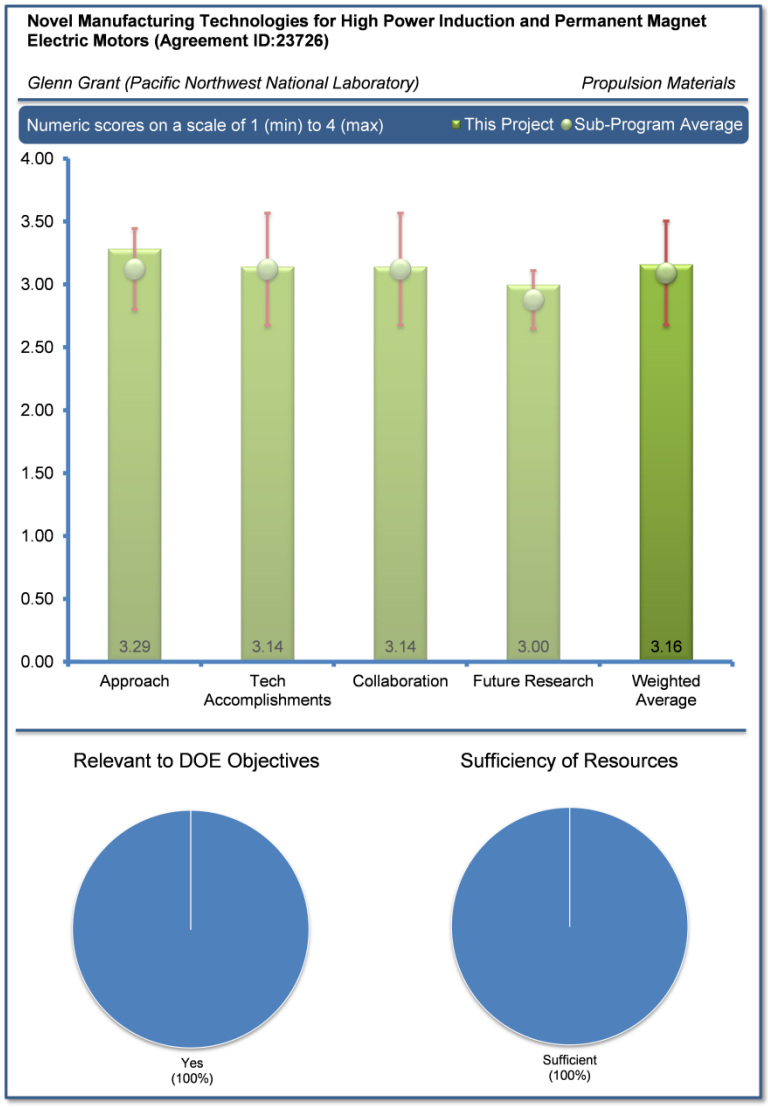
The reviewer warned that starving the materials development effort would lead to several-year delays in the commercial development of higher fuel economy engines, transmissions, and other vehicle components.

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, as well as numeric scoring responses *(on a scale of 1 to 4)*. 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 summary table presenting the average numeric score for each question for each project is presented below.

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Novel Manufacturing Technologies for High Power Induction and Permanent Magnet Electric Motors (Agreement ID:23726)	Glenn Grant (Pacific Northwest National Laboratory)	7-5	3.29	3.14	3.14	3.00	3.16
Materials Issues Associated with EGR Systems (Agreement ID:18571)	Michael Lance (Oak Ridge National Laboratory)	7-11	3.60	4.00	4.00	3.20	3.80
Durability of Diesel Engine Particulate Filters (Agreement ID:10461)	Thomas Watkins (Oak Ridge National Laboratory)	7-14	3.00	3.33	3.33	2.50	3.15
Thermoelectric Mechanical Reliability	Andrew Wereszczak (Oak Ridge National Laboratory)	7-17	2.67	3.67	3.67	2.83	3.31
Thermoelectrics Theory and Structure	David J. Singh (Oak Ridge National Laboratory)	7-21	3.50	3.33	3.33	2.83	3.31
ORNL: Low-Cost Direct Bonded Aluminum (DBA) Substrates (Agreement ID:23278)	Hua-Tay Lin (Oak Ridge National Laboratory)	7-25	3.00	2.50	2.50	2.83	2.67
Improved Organic Dielectrics for Power Electronics and Electric Motors (Agreement ID:23279)	Andy Wereszczak (Oak Ridge National Laboratory)	7-29	3.33	2.83	2.83	3.00	2.98
Advanced High Temperature Aluminum Alloys for Propulsion Applications (Agreement ID:24034)	Mark Smith (Pacific Northwest National Laboratory)	7-33	3.20	3.00	3.00	3.20	3.08
Non-Rare Earth magnetic materials (Agreement ID:19201)	Michael McQuire (Oak Ridge National Laboratory)	7-36	3.29	2.57	2.57	2.86	2.79
Mechanical Reliability of Piezo-Stack Actuators (Agreement ID:13329)	Hua-Tay Lin (Oak Ridge National Laboratory)	7-41	2.60	3.40	3.40	2.60	3.10
Materials for HCCI Engines (Agreement ID:11752)	Murali Muralidharan (Oak Ridge National Laboratory)	7-44	3.50	3.00	3.00	3.00	3.13
Tailored Materials for Improved Internal Combustion Engine Efficiency (Agreement ID:23725)	Glenn Grant (Pacific Northwest National Laboratory)	7-48	2.60	3.40	3.40	3.20	3.18
Catalyst Characterization and Deactivation Mechanisms (Agreements 9130 and 9105)	Thomas Watkins (Oak Ridge National Laboratory)	7-51	3.00	3.20	3.20	2.60	3.08
Catalysts via First Principles (Agreement ID:10635)	C.K. Narula (Oak Ridge National Laboratory)	7-55	3.17	2.33	2.33	2.67	2.58
Overall Average			3.13	3.12	3.12	2.88	3.09

Novel Manufacturing Technologies for High Power Induction and Permanent Magnet Electric Motors (Agreement ID:23726): Glenn Grant (Pacific Northwest National Laboratory) - pm004



Reviewer Sample Size

A total of seven reviewers evaluated this project.

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

Reviewer 1:

The reviewer commented that the project design showed a thought-out approach, including how the first two tasks specifically feed into the third, and that the approach focused specifically on several key needs/elements.

Reviewer 2:

The reviewer remarked that friction stir welding (FSW) approach for manufacturing of copper (Cu) alloys and components from dissimilar materials offered a promising approach to reducing material costs.

Reviewer 3:

The reviewer considered this project to have a good mix of laboratory development and eventual performance testing of the fabricated components. The reviewer stated that FSW approach was being used to join similar [Carbon (C)/ Cu] and dissimilar (Aluminum [Al]/ Cu) parts to fabricate components for rotors and stators, and to produce low-cost bulk soft magnetic materials for rotor core.

Reviewer 4:

The reviewer judged the approach to be well-designed based upon the intended application, and expressed that the results thus far appeared to effectively demonstrate the feasibility of the research for distinctly practical purposes. The reviewer revealed that the relationship between the FSW zone and the end cap/shorting bar contact area was not completely clear, however. The reviewer reported the assumption was that it must be fully electrically conductive, although the weld zone does not completely fuse the contact area. The reviewer asked if there was a potential for motor efficiency loss over time with a contact fit between dissimilar metals, and if this was a concern.

Reviewer 5:

The reviewer maintained that the approach appeared to have been well thought-out, as the FSW method appeared to be superior to any of the several other joining techniques that have been investigated. The reviewer wondered, however, if the FSW method were to ultimately not succeed, what the fallback position would have been.

Reviewer 6:

The reviewer declared that the project addressed the development of FSW for solid-state joining of high-power electric motor components used in automotive applications. The reviewer thought that the barriers and issues associated with current manufacturing processes should have been addressed in greater detail; electric motors are produced today without FSW. The reviewer wondered what barriers were being addressed. This reviewer suggested that perhaps the cooperative research and development agreement (CRADA) partner, General Motors (GM), could provide a better rationale for the development of FSW and, if successful, could clarify what the benefits would be in terms of cost, reliability, energy efficiency, enabling hybrid electric vehicle (HEV) technologies. The reviewer would like to see quantitative benefits on weight savings, higher performance, and lower cost estimates.

Reviewer 7:

The reviewer deemed the concept behind this project to be sound and of technical value, with a strong corporate partner. The reviewer further judged the joining research in Tasks 1 and 2 to be well designed, but deemed the link to the bulk materials processing in Task 3 to be unclear, and was not clarified during the presentation. The reviewer disclosed that the motivation and justification for soft magnetic materials fabrication in Task 3 was omitted, other than a statement that Advanced Research Projects Agency-Energy (ARPA-E) work was being leveraged. The reviewer reflected that it would have been good to let the reviewers know if that proposed effort was based on some prior results, suggesting this manufacturing route would be effective; and if so, to provide at least a sentence or figure supporting the prior observation.

The reviewer also stated that the presentation of progress of the Task 1 and 2 efforts would have been further strengthened and clarified by adding quantitative comparisons of the FSW weld joint properties versus other methods or earlier FSW approaches, perhaps on standardized test coupons in addition to rotor assemblies. The reviewer thought that this was particularly true where there were dissimilar metals being joined, as in Task 2. The reviewer pointed out that Slide 18 states that there are mechanical properties metrics established by the team, but provides no insight to those metrics, or how near the project is to achieving them.

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

Reviewer 1:

The reviewer found that substantial progress had been made in developing the FSW process to optimize production of copper welds. The reviewer observed that adaptive controls for temperature stabilization appeared to work well.

Reviewer 2:

The reviewer characterized the progress on the project as good, and cited the fabricated rotor component qualified the screening test.

Reviewer 3:

The reviewer saw that progress appeared adequate, given the level of resources.

Reviewer 4:

The reviewer observed that the project team had found shortcomings with existing attempts, but had also clarified necessary parameters for successful processes, particularly in the area of tool design evolution. In addition, the reviewer noted that the project team began to develop methods to address the impact of heat on the process, and how to control it. The reviewer agreed that the fabrication process appeared to pass testing.

Reviewer 5:

The reviewer felt that the accomplishments provided a clear picture of the objectives, the shortcomings/barriers, and how each has been addressed or met. The reviewer agreed that the technical merit of the research was significant based upon the intended end use. The reviewer noted the unclear association between the specific joining study and the objective of developing new alloys as a part of this program.

Reviewer 6:

The reviewer disclosed that the project had three major tasks: Cu-Cu joining; Cu-Al joining; and friction stir processing (FSP) of novel soft magnetic materials. The reviewer declared that the project had demonstrated significant progress relative to the project team's 2012 Annual Merit Review (AMR) report, but was concerned about the progress on the latter two tasks, as it was not as evident in the 2013 report. The reviewer wondered if there will be sufficient time to address the latter two tasks in the three-year project timeframe.

Reviewer 7:

The reviewer observed that the project seemed to be making some progress, but also seemed to either be behind schedule or had somewhat of an unrealistic schedule, because Task 3 had not yet begun. The reviewer revealed that the original target date for beginning Task 3 was not identified, although the presentation stated that it would begin in late 2013, which meant it would begin sometime in the third year of a three-year project. The reviewer reflected that it seemed practically unrealistic that development of a new soft magnet material, using a new manufacturing process, would be given one year or less of development effort. The reviewer further found that, on Page 25, it was stated that implementation of the new soft magnet materials developed in Task 3 would require collaboration with others who were not part of the current project. The reviewer commented that it seemed that this task was not being given adequate time or attention to achieve the stated goals, which led the reviewer to question whether realistic goals had been set for Task 3. The reviewer reported that it was stated that risks of Task 3 will be mitigated by performance gates, but pointed out that there has been no activity here yet, and higher risk efforts often take more time for success. [DOE: Program Clarification: It should be noted that the proposed future work discussed by the presenter is outside the scope of the project.]

The reviewer's primary overall concern was that the presentation showed very few actual results from this project, and the results that were shown were primarily non-quantitative or somewhat vague. It was not made clear to the reviewer if that was due to the CRADA partner restricting results, or whether there just were not yet many results to present. To this concern the reviewer cited an example; on Slide 18 it was stated that the following milestone had been completed: Characterize the microstructure and mechanical properties of Cu-Cu joints. Yet, there were no mechanical properties or successful Cu-Cu joint microstructures shown anywhere in the presentation. The reviewer reported that only microstructures with gaps and voids in the joint were shown on Slides 11 and 14, and it was not made clear if those are Cu-Cu joints from this specific study. The reviewer concluded that a slide emphasizing the properties and microstructure of that successful Cu-Cu joint and contrasting it with other non-successful welds would have been a helpful confirmation of progress.

The reviewer further observed that the presentation stated that the first Go/No Go gate had been achieved through an unidentified custom screening test, but qualified that result by stating that the rotor tested was machined from a design that will not be the prototype due to manufacturing considerations. That did not sound to the reviewer as if the originally intended goal was fully achieved, even though the authors made clear that the test was accepted as passing the gate. Again, this is where some more quantitative test or more detailed description of the custom test, or success metrics would have been helpful in assessing progress. The reviewer thought that it would have been better to present what the metrics for success were, and how close the current manufacturing process is to achieving those goals.

The reviewer agreed that the adaptive control technology is a good approach to solving the temperature control issues. However, the results shown on Slide 17 are for 6061 T6, not Cu-Cu or Cu-Al. The reviewer also suggested that the presentation would have been strengthened significantly by providing results related to Cu-Cu joining from the present study.

The reviewer saw that the actively cooled fixture seemed to be a successful response to a manufacturing barrier, but even that effort would have been more effective with some results to demonstrate its impact on Cu-Cu or Cu-Al joining. The milestone on Slide 18 states that it was developed, fabricated, and tested to allow FSW or Cu and Al rotor parts. However, the reviewer pointed out that no results were shown related to testing of that fixture, and asked what was tested, what was the outcome, and why were those results not shared.

The reviewer expressed concern that at the 50% point of the project there is not yet a FSW production process robust enough to join Cu-Cu (Slide 20). That result suggested that the prospects for joining Cu-Al were going to be even more difficult, although no results were presented related to Task 2, although Task 2 was stated to be on schedule on Slide 18.

In closing, the reviewer summarized the project as being very interesting work, but suggested that future presentations be more specific or explain why the project team cannot do so, and to include more materials-specific metrics and results from the current materials of interest.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer assessed that the CRADA with GM provides a useful distribution of capabilities between the National Laboratory and industry. Fabrication techniques and process development by Pacific Northwest National Laboratory (PNNL) with testing by industry partner is effective and should lead to good results.

Reviewer 2:
The reviewer observed that the project had a very close coordination with GM under a CRADA, and GM was also working on fabrication processes. The rotor fabricated under this project will go to GM for testing. The reviewer cited the fact that the CRADA was established as a 50-50 cost share as evidence of this close coordination, with GM providing at least half of the funding (largely through in-kind contributions of facilities, labor, and testing).

Reviewer 3:
The reviewer felt that industrial partnership has been excellent in terms of the component testing and potential eventual commercialization of the technology. However, it was not clear to the reviewer how and in what form the CRADA partner is contributing. It appeared 50% in kind share was excessive for performing a screening test.

Reviewer 4:
The reviewer reported that the study had borrowed specific fabrication requirements and parameters from the industrial partner (GM). The results of the research indicated to the reviewer a tollgate level that is, for all intents and purposes, ready for deployment on an industrial scale.

Reviewer 5:
The reviewer judged collaboration with GM to be adequate for this stage of the project, although it appeared from Slide 19 that the bulk of GM's participation would come in the motor component testing and commercial development in the later stages of the project.

Reviewer 6:
The reviewer thought collaboration with industry partner appeared sufficient to continue progress toward the goals.

Reviewer 7:
The reviewer found limited collaboration, and wondered about the CRADA with GM – if GM will buy these components from a supplier (e.g., Delphi), or if GM might actually manufacture these components. The reviewer recommended that if GM intends to go through a supplier, then there should have been a supplier on the project.

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

Reviewer 1:
The reviewer noted that the plans build upon past progress and generally address overcoming barriers. Progress to date gives confidence that the project will succeed with a high degree.

Reviewer 2:
The reviewer found that the project was moving forward based upon the 2012 results. The reviewer expected the schedule to be a challenge to complete on time, but the principal investigator (PI) indicated he expects to be able to get the rotor to GM for testing within the required schedule.

Reviewer 3:
The reviewer thought there was a good description of issues that need to be addressed for the Cu-Cu joining, but revealed there was little discussion of future plans for the Cu-Al and soft magnetic fabrication tasks.

Reviewer 4:
The reviewer was concerned about the timing of Task 3, since it was not scheduled to begin until sometime within the last year of the project. The active controls approach was good, as was the implementation of the cooled fixture.

Reviewer 5:
The reviewer observed that one of the remaining objectives that had not been addressed in detail was the solid-state processing of rotor-stator core materials. The presentation did not clarify how past progress was connected this future work, or the inherent barriers to success. The reviewer noted that general expertise in FSW processes to facilitate this research seemed to be the consistent thread, and that particular progress had been commendable.

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

Reviewer 1:
The reviewer saw that substantial weight reduction and improved efficiency appear possible and are directly in line with objectives of cost reduction and maintaining performance. Advances in adaptive control of friction stir welding process may be applicable to other production goals.

Reviewer 2:
The reviewer observed that the association between efficient and cost-effective manufacture of lightweight and reliable electric motors is inarguably clear.

Reviewer 3:
The reviewer pointed out that electric motors are critical to increased electrification of vehicles, and this project is focused upon improved cost, performance, and weight.

Reviewer 4:
The reviewer declared that vehicle electrification contributes strongly to the DOE petroleum displacement objective.

Reviewer 5:
The reviewer disclosed that high power electric motors are critical for HEVs.

Reviewer 6:
The reviewer agreed that the project addressed the development of low cost, lightweight components for the motors for HEVs and hence the displacement of petroleum use.

Reviewer 7:
The reviewer declared that, if successful, the project will help to lower the cost and weight of electric motor assemblies, thus providing an enabling step toward mass vehicle electrification.

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 resources appeared sufficient to achieve the stated milestones.

Reviewer 2:

The reviewer found that resources appeared to be sufficient, and included 50-50 cost-share from GM.

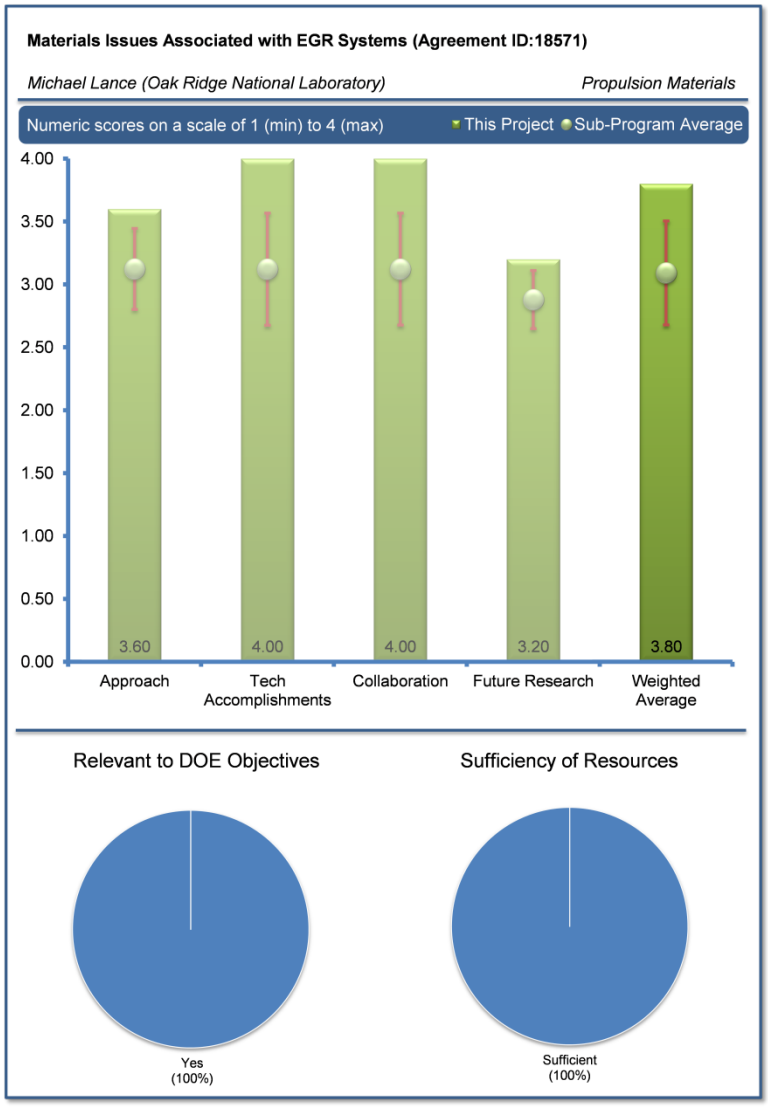
Reviewer 3:

The resources seemed to the reviewer to be sufficient for the described effort.

Reviewer 4:

The reviewer thought that, as the focus shifts considerable from joining techniques to materials processing, it would be difficult based upon past work to determine whether the budget is sufficient. The reviewer anticipated that it will be assumed that the research group has been thorough in assessing the needs of the upcoming work, and a relatively large budget amount has been earmarked for this work.

Materials Issues Associated with EGR Systems (Agreement ID:18571): Michael Lance (Oak Ridge National Laboratory) - pm009



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer declared that having a DOE lab conduct round-robin style evaluations and proposing remediation options with industry participation was a very functional approach and great role for the federally funded research and development center (FFRDC).

Reviewer 2:

The reviewer thought there was a good description of the problem and approaches to address the issues.

Reviewer 3:

The reviewer pronounced that the technical barriers to developing a strategy to mitigate exhaust gas recirculation (EGR) fouling were clearly defined. By involving all OEM's in supplying samples the problem is clearly defined. The reviewer stated that the chosen analysis methodology will lead to proposals to define solutions for the given problem.

Reviewer 4:

The reviewer held that the work has proved why high load operation can regenerate EGR by showing the changes occur in the coating. However, the approach can be improved by studying the interface of the deposit/base metal. The reviewer concluded that this will provide insight at the deposition mechanism, and ways to remove it.

Reviewer 5:

The reviewer reported that the project addresses fouling of EGR systems and the development of strategies to refresh/regenerate EGR in-situ. The approach selected focused solely on operational protocols and did not address material approaches. The reviewer questioned whether the PIs had ruled out application of materials that are resistant to fouling. The reviewer did not see any indication that the PIs understood the mechanisms involved in the fouling process. The reviewer went on to express that a good understanding of the mechanisms involved, and the impact of physical properties, the mechanics of fouling, and in-situ regeneration would greatly benefit the project team's efforts to develop protocols to clean the systems.

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

Reviewer 1:
The reviewer observed that several mechanisms were identified that suggest deposit removal can occur or conditions can be established to reduce adherence of deposits on metal surfaces. The reviewer felt that good progress had been made on understanding the formation of troubling deposits and insights on how to avoid.

Reviewer 2:
The reviewer commented that a good understanding of the fouling process was achieved, but noted that the mitigation strategies still have to be evaluated. The claimed fuel penalty for a fouled EGR is 1-2%. In case of active regeneration care has to be taken that there will be no net fuel penalty (in case of frequent regeneration). The reviewer reflected that coating with catalytic materials (provided low temperature catalytic materials exist) could be a good alternative, but noted that this was not taken into consideration.

Reviewer 3:
The reviewer remarked that the project revealed the nature of the deposits in the EGR coolers and explained the differences due to the operating conditions. Also, the mechanism of regeneration of the plugged in EGR has been explained. The reviewer reported that the nature of deposit was studied but the interaction with the surface still needed to be clarified. The deposits do not have any permanent adherence to the surface. The reviewer recommended that understanding this can help developing surface treatments to reduce deposition.

Reviewer 4:
The reviewer disclosed that the PIs appeared to have performed a number of detailed studies on the use of turbulent flow/high temperature spallation and low-temperature condensation, but that the results to the point of presentation were not sufficiently compelling to indicate their approaches will succeed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer felt that there was excellent involvement with industry. The reviewer saw that industry had input on defining most important issue for EGR cooling and performance and recommending project direction.

Reviewer 2:
The reviewer declared that the project was working with great and relevant industry partners.

Reviewer 3:
The reviewer thought the project had a strong participation/support from the whole heavy duty industry. The reviewer also noted that results are shared at appropriate level with the partners optimizing the chance of getting the results implemented.

Reviewer 4:
The reviewer reported that the PIs have on-board a number of OEMs that are providing components for analysis.

Reviewer 5:
The reviewer noted that many manufacturers and users were involved.

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

Reviewer 1:
The reviewer felt the proposed plans for future research were clearly built on the analysis of the fouling and the model developed for the fouling process.

Reviewer 2:
The reviewer recommended that computational fluid dynamics (CFD) should be a good approach to investigate geometry effects on flow velocities. The reviewer asked if experiments to date have helped to identify criteria that will be used to model the tendency for deposits to adhere, or velocity at the wall to either reduce deposit adherence or remove existing deposits. The reviewer further noted that several concepts had been identified for further research.

Reviewer 3:
The reviewer would like to see how the information on the composition will be applied in the development of the test protocols.

Reviewer 4:
The reviewer revealed that the plan did not include characterization of the interface at deposit/tubes, and suggested that it would be worthwhile to study the interface as it can reveal ways to prevent deposit building up.

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

Reviewer 1:
The reviewer remarked that, as many of the future vehicles will use EGR to improve the efficiency, it is imperative that the efficient operation of this system is well-understood. This will help increased use of this technology

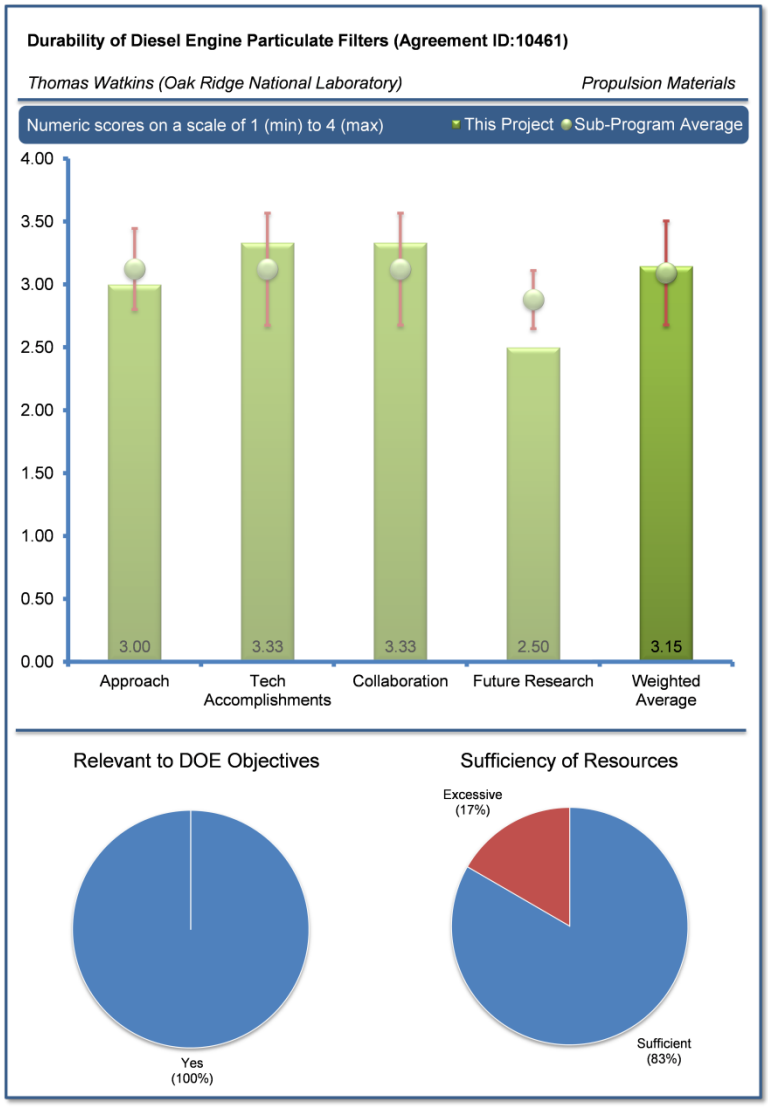
Reviewer 2:
The reviewer believed that the project would lead to an overall fuel consumption improvement of 1-2% for the heavy-duty vehicles.

Reviewer 3:
The reviewer noted that EGR performance has a direct impact on engine efficiency.

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

Reviewer 1:
The reviewer judged that the stated results should be achievable within the remaining time, but also noted that the project suffered from a reduction in funding.

Durability of Diesel Engine Particulate Filters (Agreement ID:10461): Thomas Watkins (Oak Ridge National Laboratory) - pm010



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer noted that this is a mature project with ongoing funding since 2004, possibly, which is relevant to the VTO goals. The project is providing valued data to a commercial partner to improve material properties, develop new properties, and modify regeneration protocols for diesel particulate filters (DPFs). The reviewer judged the approach to determining relevant physical and mechanical properties to be sound.

Reviewer 2:

The reviewer reported that the approach utilized existing advanced technology from Oak Ridge National Laboratory's (ORNL) High Temperature Materials Laboratory (HTML) to provide an elegant level of depth and accuracy using digital image correlation (DIC) to a relatively simple stress rig. The reviewer remarked that this, among other techniques, was an indicator of the practical and straightforward approach taken to produce useful results. The reviewer suggested that to achieve outstanding marks might involve more technologically ground-breaking test development and associated approaches.

Reviewer 3:

The reviewer characterized the project as establishing important material characterization of the different DPF materials and understanding the failure mechanisms. The reviewer noted, however, that the measuring of important properties will be needed to improve modeling.

Reviewer 4:

The reviewer disclosed that there is work being done which seems to be directed by Cummins. The reviewer asked if this is the best approach to solving the important problems.

Reviewer 5:

The reviewer reported that the project utilized a miniature tensile rig to examine materials properties such as fracture and moduli. While this information has some utility for manufacturers as they investigate various packaging and mounting strategies, the type of measurements are routine. The reviewer was left to wonder whether these types of tests are most efficiently done at a National Laboratory rather than a more cost effective contract firm.

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

Reviewer 1:
The reviewer judged that the technical accomplishments were in line with the directed efforts.

Reviewer 2:
The reviewer commented that the approaches were not overly complex, but met the needs of the customer and project goals. With a refinement in test protocols and evaluation methods, it would be very favorable to open up a study like this to a much larger matrix of candidate materials, which the reviewer suggested would be an appropriate topic for future work.

Reviewer 3:
The reviewer reported that the test machine and procedures were established to evaluate mechanical properties, and that the modulus appears to greatly impact the life prediction from the models. It appeared to the reviewer that the modulus can be difficult to consistently measure. The reviewer went on to ask how much measurement error there is in the process, and how much variation there is in the actual DPF filters due to manufacturing variations.

Reviewer 4:
The reviewer stated that the researcher presented information on microcracks and the dependency on material type, some strain maps, and a discussion on moduli but did not tie the information together into conclusions which elucidate failure mechanisms or phenomenon. The results seemed to the reviewer more in the way of observations rather than serious scientific inquiry. The reviewer remarked that the project team did not answer the question of so what.

Reviewer 5:
The reviewer felt that development of the microtesting rig combined with digital image correlation to derive Young's modulus on DPFs was a useful accomplishment. There appeared to be considerable work remaining to understand thermal properties on additional materials, however. It was not apparent to the reviewer from the presentation what progress had been made on predictive modeling. The reviewer went on to speculate that this may be due to the confidential nature of the relationship with Cummins.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the collaboration and coordination with other institutions was probably somewhere between good and outstanding, but the reviewer limited the response to good because it was unclear (due to CRADA restrictions) what specific input to technical direction that Cummins might be providing. It appeared to the reviewer that ORNL is working well with Cummins to follow an evaluation patch that is focused on the critical parameters.

Reviewer 2:
The reviewer remarked that collaboration with Cummins must be reasonably good.

Reviewer 3:
The reviewer assessed the collaboration with Cummins as good. The researcher presented the importance of the data generated on the analysis work performed at Cummins to develop DPF products.

Reviewer 4:
The reviewer felt that collaboration with Cummins demonstrates a strong industrial interest and drives the characterization research, since it appears that Cummins is providing the modeling component.

Reviewer 5:
The reviewer reported that this project appeared to be a longstanding collaborative with Cummins going back nearly ten years. It was not clear why this project has been going for so long, nor what had been accomplished over this timeframe. The reviewer suggested

that it would have been most helpful to see an overall timeline with milestones, deliverables and decision points. The reviewer wondered what would constitute success, as well as when the project will be complete and why.

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

Reviewer 1:
The reviewer stated that work on additional materials must be driven by the CRADA partner. The reviewer presumed that Cummins will continue to be interested in the development of new DPF materials.

Reviewer 2:
The reviewer observed that the future work seems to follow the same (or similar) established path - with an eye toward improving existing test techniques and adding new materials to the test matrix.

Reviewer 3:
The reviewer suggested that this project is in need of evaluation as to whether these resources should be used in a CRADA benefiting one company versus general re-application to other problem areas.

Reviewer 4:
The reviewer wondered why the CRADA is being renewed, and asked what the ultimate objectives and outcomes are. The reviewer noted that the stated work on characterization appears to be routine measurement work.

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

Reviewer 1:
The reviewer felt that there was an established clear relationship between the development of clean diesel technologies and reducing petroleum consumption due to improved efficiency of the diesel engine.

Reviewer 2:
The reviewer pointed out that the program assists in overcoming the present concern over larger-scale use of efficient diesel engines (i.e., soot generation), and that more widespread use of reliable clean diesel technology supports the DOE goal.

Reviewer 3:
The reviewer's assessment was that the project supports goals of reducing fuel consumption through development of more efficient use of DPFs and regeneration techniques.

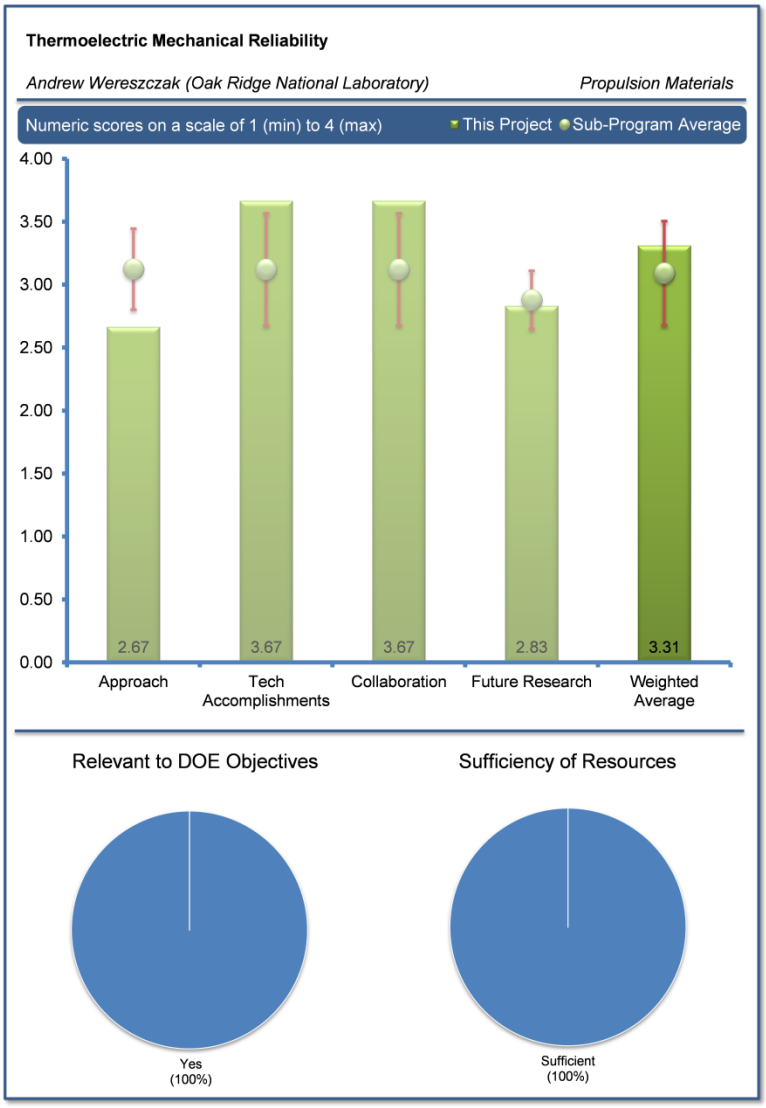
Reviewer 4:
The reviewer thought that the project could possibly support DOE goals. The reviewer considered it to be a stretch, in that it only involves using alternative fuels and controlling the particulate emissions.

Reviewer 5:
The reviewer commented that the argument for petroleum displacement is thin at best. One can see an argument for durability and cost reduction, but it was difficult for the reviewer to see how these materials studies tie back to reduced backpressure, passive regenerations, or reduced active regeneration events which have a more direct argument to fuel use.

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

Reviewer 1:
The reviewer pointed out that the program is not reliant on new or exceptional capital equipment, and appears poised to continue refining techniques within the realm of experimental approaches that the project team has developed.

Thermoelectric Mechanical Reliability: Andrew Wereszczak (Oak Ridge National Laboratory) - pm012



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer declared that this represents an ambitious three-pronged program, covering CRADA efforts (focused on determining performance of Marlow materials), International Energy Agency (IEA) activities (round-robin testing and coordination on testing techniques), and cross-cutting R&D. The reviewer saw that this appears to really represent multiple projects presented as one. The project seems to correctly rely upon first performance (property) testing and supportive materials work, and then round-robin testing through IEA (including development of testing procedures), leading to needed standardization. The reviewer noted that additional efforts ware included to specifically aid other researchers in this area (such as through development of appropriate reports).

Reviewer 2:

The reviewer remarked that overall, the approach to the project was adequate in that it addressed the needs to enhance the mechanical/performance reliability for thermoelectric materials being developed for vehicles. The project entailed stress analysis and variety of mechanical, thermal, and electrical characterizations. The reviewer noted that these characterizations are a key component to develop a reliable thermoelectric system. Further, there are additional activities such as participation in a round-robin study on the thermoelectric property evaluation and development of a fatigue test method.

Reviewer 3:

The reviewer felt that the research took an intelligent approach, which builds upon the knowledge base of Structural Ceramics. The reviewer noted that this database of mechanical properties, developed to enable high temperature ceramics for heat engine applications, is now being mined for electronic properties as well.

Reviewer 4:

The reviewer concluded that mechanical durability was the main issue, but that it is heavily dependent on how the thermoelectric materials (TEMats) are built in. In order to produce any significant amount of electricity a significant amount of heat has to pass through it. The reviewer reported that the TEMats must be a part of a dedicated heat exchanger for that to happen, and that there has to be secondary heat transfer surfaces on both sides to achieve any significant performance. Considering this, the reviewer reasoned that the integration of the TEMats with the heat exchanger surface is needed to understand the mechanical boundary conditions.

Reviewer 5:
The reviewer found that his project focused on evaluating of transport properties and mechanical reliability of thermoelectric (TE) materials/devices. Little or no technology development/innovation is evident in the project - it focuses primarily on providing a service to the industrial partners

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

Reviewer 1:
Given the modest level of resources, the reviewer found progress toward overcoming barriers to meet the objectives of the work appeared to be on track. The reviewer noted that, interestingly, despite the brittleness of the thermoelectric materials, some of the earlier work carried out by DOE and Caterpillar to place a 500 watt thermoelectric generator (TEG) on a gravel hauler truck indicated that, if properly done, the TEG would survive on the order of 500,000 miles with no interruption in output.

Reviewer 2:
The reviewer saw good progress on property measurement, but would have liked to see how this information was being used or applied by the industrial partners.

Reviewer 3:
Overall, the reviewer thought the project seemed to have accomplished a lot for a small amount of funds, even taking into account the IEA involvement (where members' countries fund their own activities). The reviewer reported that all identified milestones for 2012 were completed, and it appeared that 2013 ones are on schedule. A great deal of characterization work and testing has been completed, including development of testing procedures.

Reviewer 4:
The reviewer said that the project identified the mechanical problems with TEMats, but that characterization of thermoelectric devices (TEDs) is a somewhat fuzzy goal

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer felt the project had excellent leverage of IEA, as well as CRADA partnership with Marlow and GM involved as original equipment manufacturer (OEM).

Reviewer 2:
The reviewer agreed that collaboration with industry (part of a CRADA) and IEA has been quite effective.

Reviewer 3:
The reviewer noted that the project involved a CRADA with Marlow, as well as direct and indirect coordination and collaboration with GM (indirect through Marlow, which serves as a contractor to GM under a CRADA for development of thermoelectric devices). Plus, IEA participation ties to international interest in the project. The reviewer reported that under the IEA portion, the project is also involving universities, additional industry partners, and other government research organizations.

Reviewer 4:
The reviewer observed large participation by GM team and international collaborators.

Reviewer 5:
The reviewer declared that the whole project approach was built on supporting stakeholders, and that the project is supporting other stakeholders with characterization work.

Reviewer 6:
The reviewer suspected that the level of collaboration and coordination with industry partners could be improved by adding other potential suppliers besides Marlow, as well as end users. There appeared to the reviewer to be little interest in mechanical properties of thermoelectric materials research by the auto industry despite their increasing interest in thermoelectric technologies.

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

Reviewer 1:
The reviewer commented that there is not that much left to do, since much of the project is scheduled to end soon. Remaining efforts planned seem important, including getting the word out on design approaches and concerns. The reviewer was concerned about whether the remaining time is sufficient to complete all planned tasks.

Reviewer 2:
The reviewer reported that the project is about 93% complete. The future work presented appears to be completion of the on-going activities in the various areas of characterizations, fatigue test method, and participation in the round robin study.

Reviewer 3:
The reviewer judged the future work to be more of the same, but that the 500°C work was important because it has the biggest potential to support petroleum displacement targets.

Reviewer 4:
The reviewer felt that it would be useful to see what metrics, goals, and targets are available for the different designs. The reviewer asked what the minimum mechanical strength requirements were, and if the devices being studied were meeting these goals.

Reviewer 5:
The reviewer observed that this work is nearing completion, and yet it is not clear what next steps need to be taken to ensure industrial application of these materials.

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

Reviewer 1:
The reviewer's assessment was that durability and reliability would be critical for successful implementation of TE devices, as mechanical properties are critical in the design stage of TE devices.

Reviewer 2:
The reviewer found that the project focused on improvements of materials for thermoelectric applications, and reported that thermoelectrics are expected to help improve efficiency of vehicles significantly.

Reviewer 3:
The reviewer evaluated the 500°C work to be important since that has the biggest potential to support petroleum displacement targets.

Reviewer 4:
The reviewer believes that enabling the use of TE to harvest waste heat will improve vehicle fuel economy, if only a few percent. Such usage will support the overall objectives of DOE for petroleum reduction in vehicles.

Reviewer 5:
The reviewer observed that the impact of on-board electrical power generation on petroleum displacement was inferred but never directly quantified or even projected for ICE, Hybrid, or electric vehicle (EV).

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

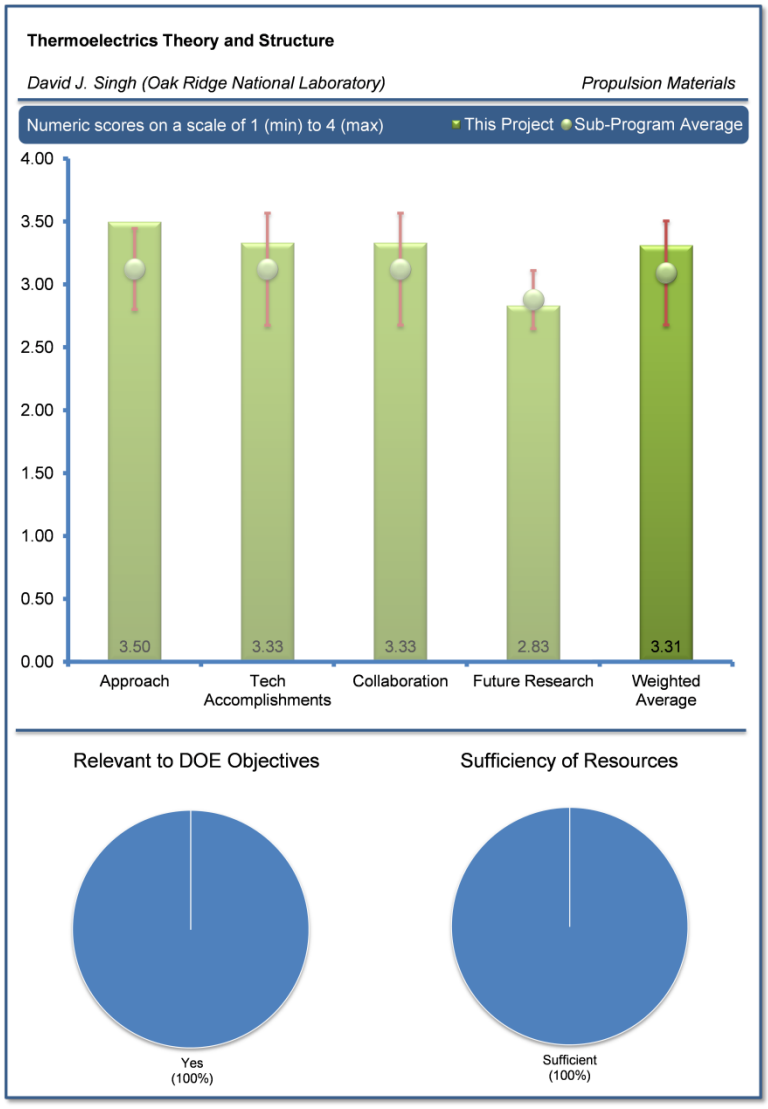
Reviewer 1:
The reviewer said that it seemed like DOE is getting a lot of bang for the buck from this project, even taking into account the testing funded by others through IEA.

Reviewer 2:
The reviewer thought that resources for this project appeared adequate to achieve the stated milestones in a timely manner.

Reviewer 3:
The resources provided appeared to the reviewer to be sufficient for the completion of the milestones in the suggested time frame.

Reviewer 4:
The reviewer found it difficult to judge the adequacy of resources for this project.

Thermoelectrics Theory and Structure: David J. Singh (Oak Ridge National Laboratory) - pm013



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer found the approach to be exactly right. Thermoelectrics do not exhibit the cost/performance required for vehicle applications by far. The reviewer felt that this work addresses these issues in the correct way.

Reviewer 2:

The reviewer thought that there was an excellent approach that has defined targets [figure of merit (ZT) greater than 2 for heat recovery; greater than 1 for cooling], and includes fundamental of TE performance (Seebeck) based on first principles.

Reviewer 3:

The reviewer reported that this work is in the early stages of development and is quite basic in nature, but agreed that this is exactly the type of research that the federal government should be supporting.

Reviewer 4:

The reviewer reported that much of the effort under this project is focused upon the first detailed look at certain materials for thermoelectric applications, and could lead to significant improvements in materials utilized for these applications. The specific focus for this project is to identify materials, but leave the validation to others.

Reviewer 5:

The reviewer observed that the project addresses a very important problem of waste heat recovery using novel thermoelectric materials. This computational study is important in designing new materials and predicting their properties. However, the end goal of the study is not clear. The reviewer asked if this work relates to any experimental thermoelectric material development, since it seems that the fundamental work needs to be related to thermoelectric material development to realize the target goals of ZT and cost. Further, the reviewer wondered if the proposed materials are easily fabricated, what their material properties are, what the costs are, etc. The reviewer finally suggested that practical viability of the material needs to be discussed.

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

Reviewer 1:

The reviewer reported that the project has identified big potential improvements.

Reviewer 2:

The reviewer noted that the project team had expected to identify one low-cost material for 300-600°C operation, but ended up identifying three. Also identified were two promising materials for room temperature operation. Finally, the project identified a high-performance material that had been previously overlooked. Overall, the reviewer felt that the project team seemed to have not only found good materials, but figured out why these materials performed better.

Reviewer 3:

The reviewer judged that the identification of potential new thermoelectric materials which lack toxic or expensive/rare elements is a very worthy goal. The reviewer saw that so far significant progress is being made toward this objective of identifying new potential material compositions which exhibit thermoelectric capabilities.

Reviewer 4:

The reviewer reported that there was good progress on new novel compounds. The reviewer noted, however, that no mention is made of the Mo3Sb7 compound identified in Fiscal Year (FY) 2011/2012. It was not clear to the reviewer why no mention was made, and raised the questions of why this was apparently abandoned. In FY 2013 review, the reviewer reported that the project team has three new materials.

Reviewer 5:

The reviewer wondered what the implications might be of using the two identified materials, which both have lead, a toxic metal. The reviewer was also not sure what the implications were that all external collaborations have been discussions or communications. The reviewer asked if anyone was fabricating a device based on these materials or if this was just an academic exercise.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer reported that the research was published which was a good way to make an impact. The reviewer remarked that since thermoelectrics is in such an early stage, it is truly precompetitive and the right way to collaborate.

Reviewer 2:

The reviewer noted that the project team was working with the automotive industry (including multiple manufacturers), universities, and other research organizations (including the Naval Research Laboratory). The reviewer thought that this approach should really help to get the word out on results, which will be key to the value of this project.

Reviewer 3:

The reviewer found that the investigators had assembled a diverse project team for a primarily fundamental study on thermoelectric properties including both significant industrial partners (OEMs) and reputable academic institutions.

Reviewer 4:

The reviewer felt that collaboration and coordination with other institutions could be improved, but since the work appears to be rather fundamental, it may be too soon for such detailed collaboration.

Reviewer 5:

The reviewer was left unclear on the role of the collaborators the project, and asked the presenter to please be more specific on their roles.

Reviewer 6:

The reviewer commented that specific details of the various collaborations needed to be discussed.

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

Reviewer 1:
The reviewer felt that focusing on low cost was the right thing to do.

Reviewer 2:
It seemed to this reviewer that the project had a lot planned for the remaining 16 months or so to go, particularly compared to what has been accomplished so far. The reviewer was definitely concerned about the project meeting schedule requirements. Also, most of the future efforts are simply focused upon identifying potential materials, not on the experimental results (for validation by others).

Reviewer 3:
There appeared to the reviewer to be a lack of connectivity or transition from this theoretical work and a strategy to develop a practical usable material.

Reviewer 4:
The reviewer thought that future research planned needed to be made more explicit. For example, if the atomic structure of these new material compositions is not well established, then the work should be done to determine what that structure is and how best to formulate their production.

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

Reviewer 1:
The reviewer found this project to be highly relevant - to improve vehicle efficiency, high efficiency thermoelectrics are needed, and to get that efficiency from thermoelectrics, better materials are required. That is exactly what this project is aimed at. The reviewer declared that many industry members are looking to incorporate thermoelectrics, so there is strong potential for petroleum savings if efforts are successful.

Reviewer 2:
The reviewer suspected that extensive usage of thermoelectric materials will necessitate the ability to manufacture greatly increased quantities of these materials; and therefore it is incumbent to develop the means to do so. Before that can be accomplished, it is necessary to have a validated database of materials composition and thermo-mechanical properties. In particular, the new materials must have no toxic or expensive elemental components. The reviewer judged that usage of thermoelectrics to harvest vehicle waste heat or to provide occupant comfort will support the overall DOE objective of petroleum reduction.

Reviewer 3:
The reviewer said that, yes, there are a few applications where thermoelectrics make sense for petroleum displacement. For example, waste heat recovery (WHR) for the EGR circuit – many of the future downsized engines will have EGR coolers. The reviewer cited this as the ideal application since there is a temperature difference big enough to give a significant output. There is also already a cold sink in place today so the added cost, weight and complexity is manageable. The reviewer noted that other WHR systems are far too expensive for cars. However, the reviewer did not see the relevance for air conditioning, since the efficiency of an air conditioning system is above one if designed for efficiency. Thermoelectrics have an extremely low efficiency at air conditioning temperatures in comparison.

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

Reviewer 1:
The reviewer observed that resources appeared sufficient for now, though the project team would clearly continue to evaluate additional materials if it received additional funding (and time).

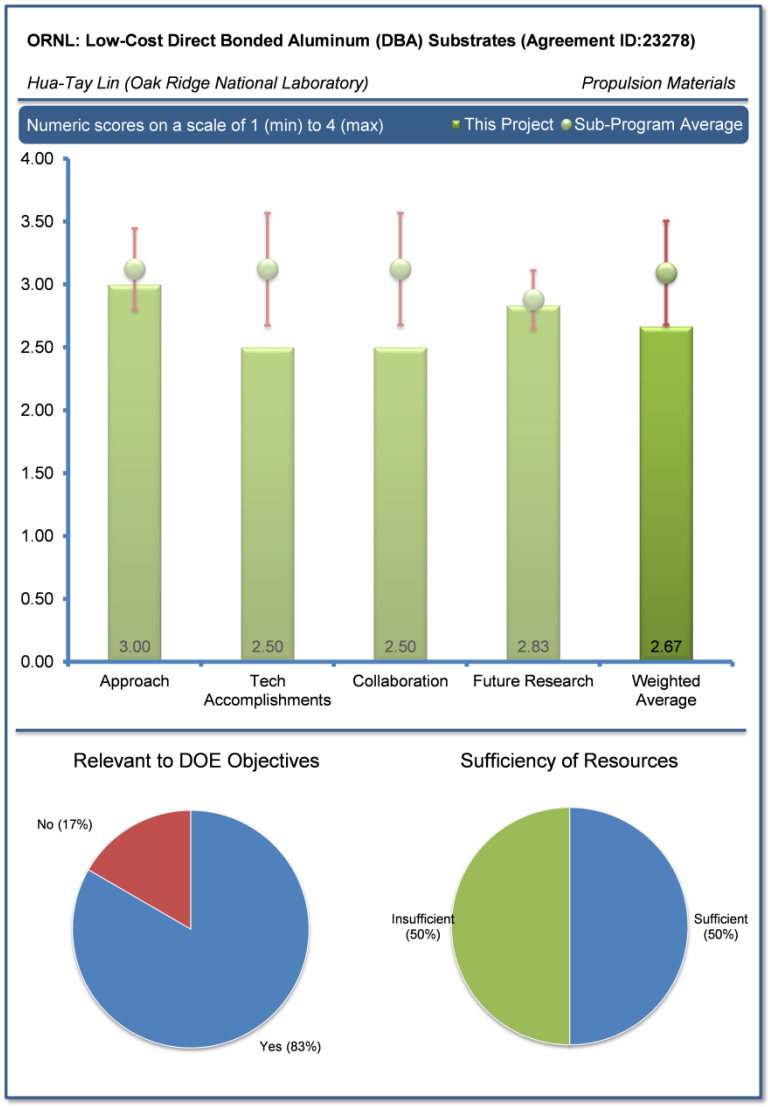
Reviewer 2:

The reviewer felt the resources seemed appropriate but could not really judge the effort, although the reviewer also thought there were an impressive number of publications for the money.

Reviewer 3:

It was the reviewer's view that at this stage of the work, there is no strong imperative to increase funding, and therefore resources appear adequate to achieve the stated milestones.

ORNL: Low-Cost Direct Bonded Aluminum (DBA) Substrates (Agreement ID:23278): Hua-Tay Lin (Oak Ridge National Laboratory) - pm036



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer found that the program addressed all relevant issues including strength, thermal conductivity, and cost with benchmarking against commercially available direct bonded aluminum (DBA) and direct bonded copper (DBC). To support future high temperature wide bandgap (WBG) electronics, an assessment of the reliability of these substrates to long-term high temperature operation and thermal cycling should be conducted. It was not clear to the reviewer what the cost targets were or what savings might be realized from the ORNL-developed technologies.

Reviewer 2:

The reviewer thought that the initial approach to assessing the market, performing tests on low-cost substrates and benchmarking were reasonable. The reviewer felt, however, that there was insufficient discussion on the approach towards developing material parameter improvements in silicon nitride (Si_3N_4) compositions.

Reviewer 3:

The reviewer said that this was interesting work but there were unanswered questions about residual stresses perhaps imparted during the bonding process. The reviewer felt that the work may be a solution looking for a problem: This means that the work seems to be like a product improvement project that industry might be able to do on its own.

Reviewer 4:

It was the reviewer's view that the project addressed a critical problem of DBA for power electronic applications. With higher power density electronics being developed, need is for more reliable joints with appropriate thermal conductivity materials. The reviewer reported that the project is investigating DBA fabrication with various ceramics, and that the project is actively seeking low-cost, large scale manufacturing approaches for DBA fabrication.

Reviewer 5:

The reviewer cautioned that the technical approach to using high-vacuum to process alumina-forming alloys was going to be an uphill battle from the beginning unless involving reactive brazing or reducing atmosphere processing.

Reviewer 6:
The reviewer felt that a significant barrier at this point may be time – for a project in the final planned funding year there is still a considerable amount of valuable work being proposed, particularly with regard to the optimization of the Si_3N_4. Much of this work is planned for completion in FY14, although this particular project ends in 2013 – presumably there is another source of funding for this work.

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

Reviewer 1:
The reviewer thought the progress on the project has been on track per the proposed milestones. Various brazing materials have been investigated. Silicon nitride-based substrate materials with optimized properties have been developed. The reviewer found the strategy to develop silicon nitride ceramics which optimize thermal conductivity using appropriate sintering elements to be excellent.

Reviewer 2:
The reviewer saw that, while the work being performed was significant, the technical challenges with substrate bonding for various systems appear not to have been overcome. The reviewer deemed promising some studies that are planned to improve this, but little in the way of accomplishment thus far (this could change significantly over the remainder of the program). The reviewer found that the largest breakthroughs seem to be in the area of the mechanical performance of the Si_3N_4, and the qualities being presented are intriguing. This appeared to the reviewer to be a direct follow-on on earlier work, however, and not necessarily an outcome of this program; the mechanical properties listed on Slide 17 are attributed to work published in 2010, which was before this specific program was funded.

Reviewer 3:
It appeared to the reviewer that the accomplishments to date were largely in the area of trial of unsuccessful bonding techniques and assessment of key thermal and mechanical properties of existing materials. The reviewer felt that this is a good start on bounding the issues associated with development of improved substrates.

Reviewer 4:
The reviewer felt that progress has been good. It was unclear to the reviewer what the ultimate objectives (quantitative) were, leading the reviewer to ask how the reviewers will know when the work is done.

Reviewer 5:
The reviewer warned that milestone three may not be completed due to budget changes.

Reviewer 6:
The reviewer stated that if the objective was lowering the cost of DBA manufacturing, then progress has been poor. The reviewer went on to say that although a shift to Si_3N_4 and DBC may be a more fruitful pursuit, it seems to be a re-direction of the intended purpose of the project.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer saw that collaboration with the Advanced Power Electronics and Electric Machines Program (APEEM) team members and industrial partners/suppliers appeared to have been quite fruitful for the project. Benchmark testing using Marlow DBA substrate is particularly important task. The reviewer went on to suggest that potential licensing of the DBA for silicon nitride ceramics to industry exists.

Reviewer 2:
The reviewer found ample evidence to suggest that the program has engaged outside entities to support the work, as the collaboration with Marlow has been established. The reviewer noted that direct contribution from Marlow appeared limited to the supply of material for benchmarking, so this collaboration (along with others) should be pursued more aggressively.

Reviewer 3:
The reviewer reported that this seems to be primarily a team within ORNL and industry involvement is limited to Marlow and Materion providing material.

Reviewer 4:
The reviewer expressed that collaborations appeared limited to obtaining materials from vendors, and was unclear what the relationship was with the National Transportation Research Center (NTRC).

Reviewer 5:
The reviewer said that, other than supplying components or materials for some aspects of the work, it was unclear the extent of collaboration with other industrial partners.

Reviewer 6:
The reviewer recommended that the project expand partnerships with industry and universities [e.g., Virginia Polytechnic Institute Center for Power Electronics Systems (CPES)].

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

Reviewer 1:
The reviewer thought the difficulties encountered with successful bonding and the shortcomings of DBA-type systems had been presented adequately. The reviewer stated the future research path has the potential to overcome a number of these issues.

Reviewer 2:
The reviewer relayed that enhancements to present properties of Si_3N_4 ceramics are possible and the proposed approach for attaining improvements seemed reasonable. The reviewer concluded that completing the evaluation of tape casting products will support the overall benchmarking effort.

Reviewer 3:
The reviewer found that future work adequately addresses the milestones and deliverables of the project. However, it was not clear to the reviewer how low-cost silicon nitride ceramic will be developed using a high purity silicon powder. This seemed to be counterintuitive.

Reviewer 4:
The reviewer reasoned that since bonding of ceramics and other materials seem to fail in the region adjacent to the joint, it is important to determine if the process imparts large residual stresses in this region. There are models which seek to predict these residual stresses, which should at least be investigated for applicability.

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

Reviewer 1:
The reviewer thought that this project addressed an enabling technology for the reliable thermal management of high power density electronics for HEVs or EVs, thus leading to significant petroleum displacement.

Reviewer 2:
The reviewer claimed that, yes, high performance substrates are critical for future WBG electronics that will have significant impact on efficiency, mass, and cost.

Reviewer 3:
The reviewer observed that lighter-weight, more efficient and reliable DBAs could lead to less costly power modules in EVs, thus pushing down the costs. It was not clear to the reviewer how much cost savings was possible, although it appeared to be minimal.

Reviewer 4:
The reviewer saw that the relationship between this program and petroleum displacement seemed to exist through efficiency and reliability of electronics, but remarked that the direct path between the concepts was not clearly presented.

Reviewer 5:
The reviewer thought there was small relevance to the DOE objective of petroleum displacement (e.g., bonding on ceramic engine valves), but it was unclear how much this contributes to engine powertrain efficiency improvement.

Reviewer 6:
The reviewer reported that the impact on petroleum displacement was not discussed. The power electronics application was not even mentioned until the summary slide. In the reviewer's opinion the case for relevance was not made in the presentation.

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

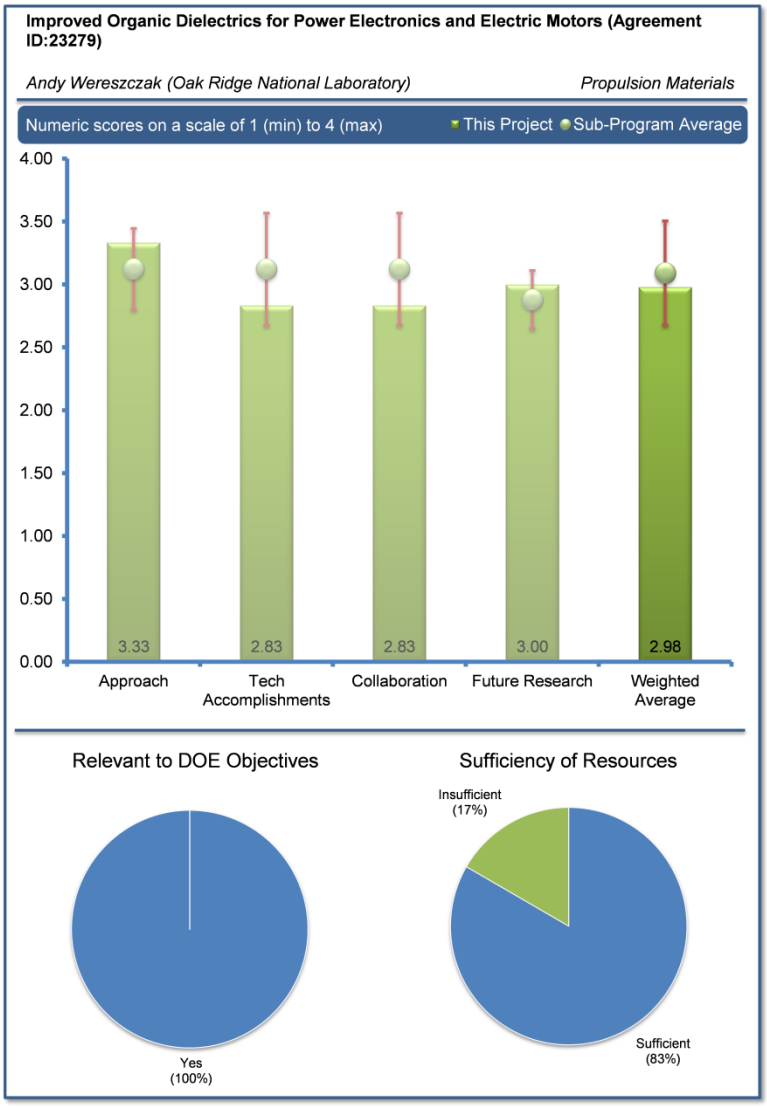
Reviewer 1:
The reviewer stated that overall the resources appeared to be sufficient but suggested that perhaps the industry partners could contribute a higher percentage of the project cost.

Reviewer 2:
The reviewer relayed that it was acknowledged in the early slides that budget changes may alter a FY 2013 milestone.

Reviewer 3:
The reviewer declared that additional resources will be needed to support substrate needs of future WBG electronics.

Reviewer 4:
The reviewer found that funding was not sufficient to support proposed work.

Improved Organic Dielectrics for Power Electronics and Electric Motors (Agreement ID:23279): Andrew Wereszczak (Oak Ridge National Laboratory) - pm037



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer thought that this was a nice piece of work; well thought-out and planned. The reviewer also thought that this appears to be a good return on investment.

Reviewer 2:

The reviewer felt that the project would return a solid set of conclusions on the relative strengths of different approaches, because the test matrix encompasses a large number of candidate fillers. It was not entirely clear to the reviewer why other classes of materials (outside of oxides) were not a significant part of the evaluation; as it might have been more transformational in nature for the intended applications due to much higher levels of thermal conductivity.

Reviewer 3:

This work seemed to the reviewer to be closer to basic applied research, which is very appropriate for federal funding. The approach is very straightforward but perhaps too heuristic. The reviewer asked if there was any theoretical work which might contribute to faster progress to finding better materials.

Reviewer 4:

The reviewer reported that the project is related to developing thermal management strategies for power electronic devices using thermally conductive molding compounds. Increased heat dissipation can lead to reliable performance of the power modules and longer lifetimes, thus contributing to cost savings. The reviewer relayed that different conductive filler materials added to the epoxy materials to enhance thermal conductivity are being investigated.

Reviewer 5:

The reviewer disclosed that the project used magnesium oxide (MgO) as filler in epoxy to improve thermal performance, and presented a wide range of fillers and cost estimates. The reviewer also noted additional work on durability and impact on life due to thermal cycling, mechanical forces, and vibration before these materials are suitable for use in production motors and power modules.

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

Reviewer 1:
The reviewer felt there was an excellent review of candidate materials, with a good combination of predictive modeling and experimental results. The reviewer also reported that the target of 3 W/mK (watts per millikelvin) achieved through a process of material evaluation, modification, modeling and cooperation with industry.

Reviewer 2:
The predictive models are effective, and the approach to determining the relative effectiveness of each filler distribution and type is adequate. More in-depth testing based upon actual usage conditions appears to be slated for future efforts.

Reviewer 3:
The reviewer felt that progress and technical accomplishments were moving forward to the objective of greater than 5 W/mK, but the reviewer was still not clear what the barriers might be to achieving this goal from the 3 W/mK level achieved.

Reviewer 4:
The reviewer saw that good progress was being made, but observed that some results appear to be identical to results presented last year (i.e., Slides 8 and 10).

Reviewer 5:
The reviewer deemed progress on the project to be adequate. Epoxy formulations have been developed with thermal conductivities of 3 W/mK from the baseline value of 0.2 W/mK. Synthesis and process strategies have been developed. Models have been developed to assess the temperature reductions in various electronic modules by using the conductive polymers. The reviewer reported that tests conducted on the magnetic and electrical characteristics of the developed formulations shows their acceptable performance. However, the reviewer wondered if these materials perform under long-term exposure to natural elements such as moisture, etc., or if thermal cycling affects the performance. It was not clear to the reviewer why the thermal conductivity goes up and not the electrical conductivity in these formulations.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer judged, based upon the budget, that the right collaboration level appeared to be in place. The collaborative role of the MgO supplier did not appear to be significant outside of providing filler materials.

Reviewer 2:
The reviewer noted that collaboration with a key industrial partner, SolEpoxy, was likely providing useful data for both the manufacturer and the researchers.

Reviewer 3:
The reviewer reported that collaboration with the industrial partner that is a supplier to the electrical and motor component manufacturers is important, and noted that this will certainly help in the technology commercialization and adaptation.

Reviewer 4:
The reviewer would have expected greater involvement of more industrial partners, given the importance of this work to electric and hybrid vehicle propulsion systems.

Reviewer 5:
The reviewer rated partnerships with the feedstock material suppliers to be good, but there was no direct connection, and thus technology path, to industry. The NTRC was referenced as an end-user/industrial partner which is another research institution (via ORNL), not a true industrial user.

Reviewer 6:
The reviewer recommended that collaboration with motor and power module manufacturers would provide valuable feedback from end user on durability and other issues.

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

Reviewer 1:
The reviewer found that the future work being proposed was an effective mix of building upon past work and refining the evaluation protocols. The scope still seemed to the reviewer to be relatively limited, but the budget allocation may be restricting this.

Reviewer 2:
The reviewer reported clearly defined future work.

Reviewer 3:
The reviewer stated that future work includes further increase in thermal conductivity up to 5 W/mK, and demonstrating the heating effects of the molding compound. Further, the material is planned for implementation on an electric motor component. The reviewer questioned whether all these activities could be completed in the remaining fiscal year.

Reviewer 4:
The reviewer recommended that basic research on new low-cost filler materials with superior thermal/electrical/dielectric properties should be pursued as an adjunct to this work.

Reviewer 5:
The work did not appear the reviewer to be focused on identifying and addressing the barriers to achieving the goal.

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

Reviewer 1:
The reviewer thought this project was very relevant, since improved thermal performance will lead to higher power density in electric drive system components.

Reviewer 2:
The reviewer concluded that this project addressed an enabling technology for the reliable thermal management of high power density electronics for HEVs or EVs, thus, leading to significant petroleum displacement.

Reviewer 3:
The reviewer found that the direct support was not as significant as other programs, but increased efficiency and reliability of electric components still played a role in reducing energy consumption, which invariably includes petroleum.

Reviewer 4:
The reviewer stated that vehicle electrification contributes strongly to the DOE petroleum displacement objective.

Reviewer 5:
The reviewer relayed the project improved the thermal reliability of power electronics.

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

Reviewer 1:
The reviewer recommended additional resources to include research on improved filler materials.

Reviewer 2:

It was unclear to the reviewer whether funding would be sufficient in FY 2013 to complete the tasks listed in Future Work slide. The reviewer expected that additional funding in FY 2014 would provide additional funds needed.

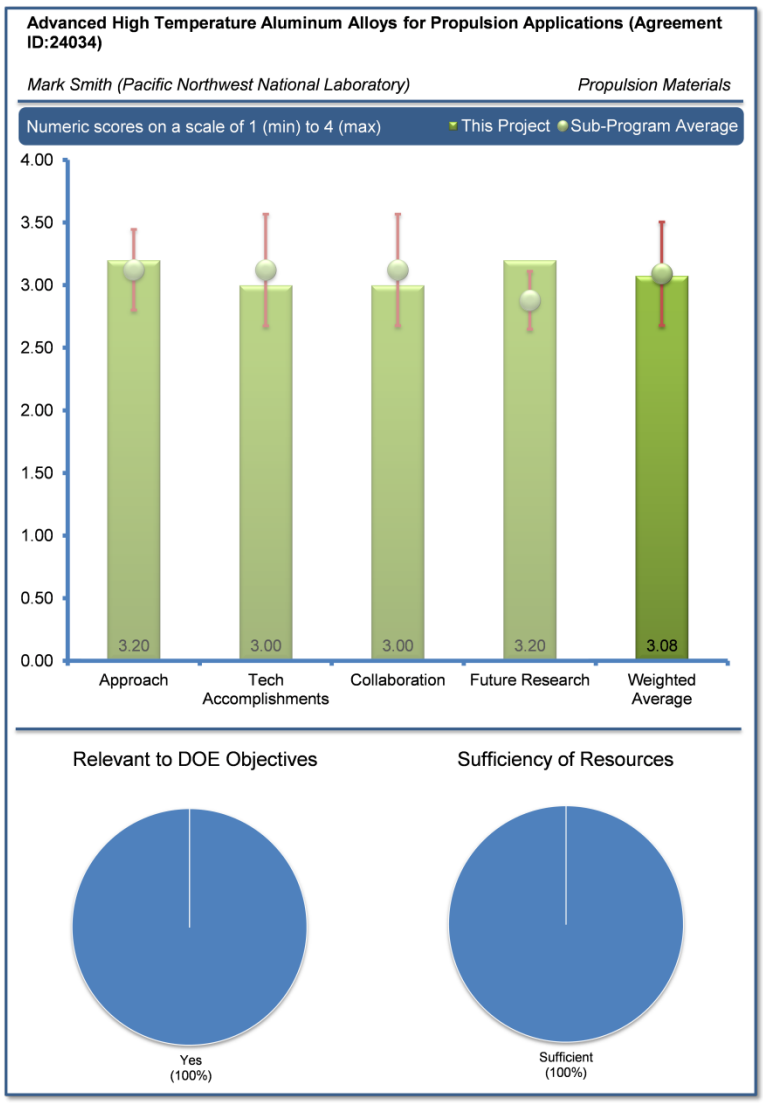
Reviewer 3:

The reviewer thought the resources seemed sufficient based upon the proposed scope, but the relative allocation for FY 2013 is quite small compared to earlier years in the program.

Reviewer 4:

The reviewer judged that the resources appeared to be sufficient to continue timely progress.

Advanced High Temperature Aluminum Alloys for Propulsion Applications (Agreement ID:24034): Mark Smith (Pacific Northwest National Laboratory) - pm044



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer thought the team had a good approach to developing an alloy, and a manufacturing process to produce it.

Reviewer 2:

The reviewer declared that development of new alloys is not a simple task. The reviewer judged the current approach to be good, concentrating on one system with small variations; however, the reviewer would have liked to see justification of why a particular alloy system was chosen.

Reviewer 3:

The reviewer reported that the original goal was to reach 300 MPa (megapascal) tensile strength at 300˚C, but that this goal had been changed to 250 MPa, and as a result not all technical barriers were tackled in phase 2 of the project. The reviewer concluded that the approach was solid and scientifically well chosen. The microstructure of this material is quite different from standard Al, which makes it desirable to have a broader evaluation of the material characteristics, like corrosion resistance.

Reviewer 4:

The reviewer found it strange that Transmet was not involved from the beginning, as Transmet and Cummins are both based in Columbus, and Transmet specializes in this very technology. The reviewer stated that it should have been advantageous if Transmet had been a bigger partner in this work, and that it should also have been advantageous to have a few components identified upfront with given requirements to meet.

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

Reviewer 1:

The reviewer observed excellent process towards developing something that could be commercialized in the near future.

Reviewer 2:

The reviewer found very good progress with the alloys showing good properties at 300˚C. Even though the extruded structure is not quite uniform with large scale segregation of phases the properties are significant. The reviewer recommended that efforts should be

made to assess the effect of long time holding at high temperatures on the structure. Also, the high-temperature corrosion behavior of the new alloys needs to be evaluated.

Reviewer 3:
The reviewer reported that the project was being executed according to plan. In the original plan Kaiser Aluminum had a role as material provider this was taken over by Transmet. During the presentation evidence was provided that this should not influence progress. The reviewer found the progress towards DOE goals difficult to evaluate since it is unknown for what part this is used and as such it is not possible to establish the potential fuel economy benefit.

Reviewer 4:
The reviewer commented that the need for a stronger extrusion machine was identified, which indicated a potential wear problem for the extrusion machine. The reviewer would have expected more results considering the funding size. This lack of results indicated to the reviewer a number of failures that have not been reported. Also failures are worth reporting. That is what we learn from. The reviewer commented that this was a sound project addressing the need to reduce weight to safe fuel.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer found that there was good collaboration with industry partners. It was clear to the reviewer that a good relationship had been built with Transmet.

Reviewer 2:
The reviewer judged there to be a good, well-coordinated, collaboration with industry, but suggested that cooperation with universities could have been beneficial to have a basic evaluation of a wide variety of this material's characteristics.

Reviewer 3:
The reviewer reported that the entire process team was included; this will make commercialization quite easy.

Reviewer 4:
The reviewer reflected that collaboration was limited to three partners. The reviewer suspected that others are probably watching and will participate based on favorable materials research and cost to produce.

Reviewer 5:
The reviewer stated that an Al processing company should have been identified from the start.

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

Reviewer 1:
The reviewer pronounced that there were solid plans in place for future development toward the possible commercialization of this material.

Reviewer 2:
The reviewer felt that the plan was clearly described in milestones, and that there was a clear focus on producing an engine component.

Reviewer 3:
The reviewer relayed that there was a plan for large-scale production and field testing; this is good progress. However, the reviewer recommended that the corrosion at high temperature be evaluated before commercialization, and pointed out that this is not currently included in the future plan.

Reviewer 4:
The reviewer reported that the project is on the path to conclude in calendar year (CY) 2014, and there were no indications of follow-on work, or of any manufacturing interest to date. The reviewer suggested a marketing strategy to determine what company may be interested in producing bulk alloy.

Reviewer 5:
The reviewer said that this seems to be trial and error, performing some tests and seeing where this is going. The reviewer felt that targets, components, and requirements were not identified.

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

Reviewer 1:
The reviewer expected that as the new powertrain is expected to perform at higher temperatures, conventional Al alloys may not perform well. Replacing them with titanium may increase the cost and weight. The reviewer concluded that development of new Al alloys with high temperature capability will help in maintaining the weight while increase the performance.

Reviewer 2:
The reviewer agreed that reduced weight is very important.

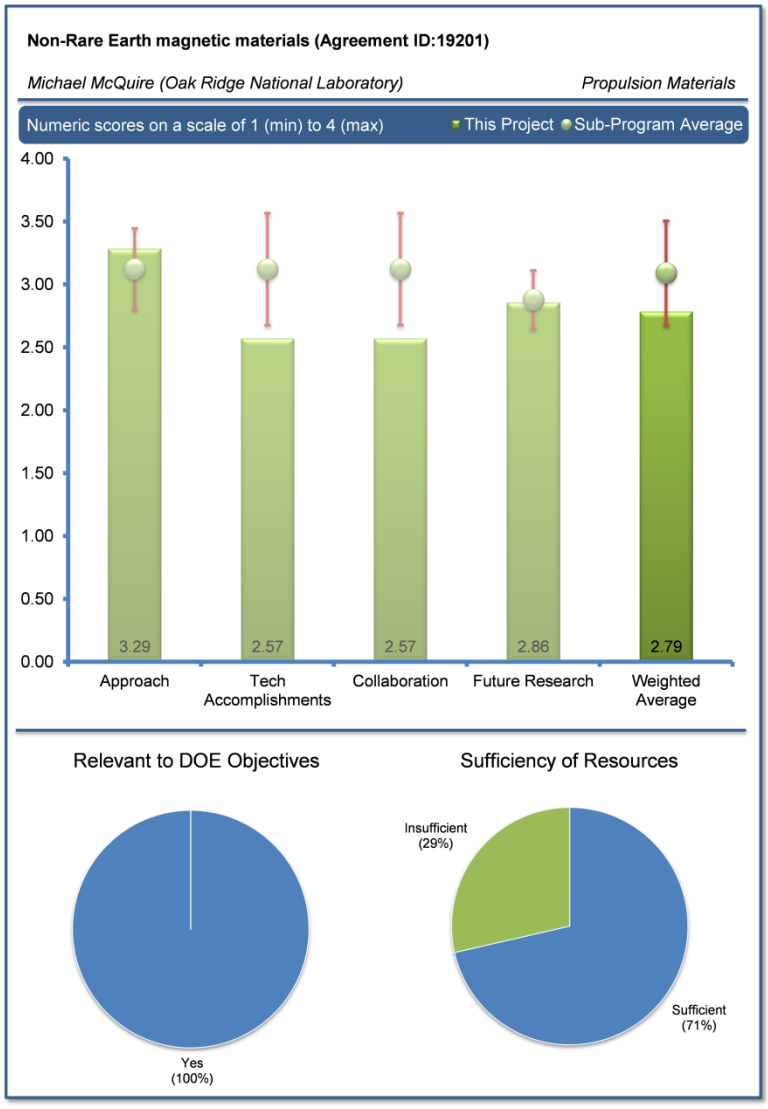
Reviewer 3:
The reviewer stated that higher allowable temperatures in general lead to higher fuel efficiency. The reviewer had to guess that this will actually be the case, since the applications were not disclosed.

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

Reviewer 1:
The reviewer judged the resources to be in line with the requested work volume.

Reviewer 2:
It was not clear to the reviewer what the contribution from Cummins was in the project.

Non-Rare Earth magnetic materials (Agreement ID: 19201): Michael McGuire (Oak Ridge National Laboratory) - pm045



Reviewer Sample Size

A total of seven reviewers evaluated this project.

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

Reviewer 1:

The reviewer felt that the team had an excellent pragmatic approach to new materials development, combining chemical intuition, supplemented with first-principles computation, followed up with synthesis and characterization. It is easy for this type of exploratory work to wind up in the weeds, but this project is mostly staying focused on promising directions.

Given the relatively small global supply of hafnium, it was not entirely clear to the reviewer that magnet chemistries based on hafnium would be such a great advance compared to rare earth chemistries. This is particularly true if the measured energy products of the hafnium-based magnets are closer to Alnico than to rare-earth magnets. Considering this, the reviewer reported that the team has identified directions to address these issues (possible substitution of zirconium (Zr) for hafnium (Hf), and improved processing to increase the energy product) as work items for FY13. Overall, the reviewer was not fully convinced that pursuing hafnium-based chemistries is preferable to improving existing chemistries such as Alnico.

The reviewer felt that the most promising direction to achieve energy products comparable to rare-earth magnets using lower-cost materials seems to be the thermomagnetic stabilization of $L1_0$ iron (Fe)-palladium (Pd)-nickel (Ni). The initial progress on this front is encouraging. The reviewer thought it would be interesting to see the outcome of the FY13 work.

Reviewer 2:

The reviewer saw that the project appeared to be well thought-out, relevant to the objectives and directly targeting technical barriers largely through the attempts to develop new, non-rare-earth based magnetic materials.

Reviewer 3:

The reviewer relayed that this project addressed the development of non-rare earth magnetic materials for automotive applications. The project focused on identification of heavy transition metals as potential replacements for rare-earth magnets. The reviewer thought that there were well-defined targets and barriers are presented.

Reviewer 4:

The reviewer reported that the project approach included both theoretical and experimental activities to develop low-cost permanent magnet materials. The project was multi-disciplinary and involved theory/computations, processing, and characterizations. The reviewer observed that use of high magnetic fields to stabilize ferromagnetic phases has been shown to be successful.

Reviewer 5:

The reviewer considered the research to be important, and reflected that the potential dependency on rare earths in large supply is somewhat frightening. Unfortunately, the reviewer felt the approach and selection of the range of systems did not clearly come across. The reviewer was left wondering what the relative cost of an advanced iron-based system versus Hf-cobalt (Co)-boron (B) was, and how this compared with fractional differences or orders of magnitude, as cost is a critical driver to this research. The reviewer reported that there were promising results on the Hf-Co-B system that would be continued with substitutions for more common elements, so the focus was not absent.

Reviewer 6:

The reviewer declared that one of the primary technical barriers was cost, and the cost component was not addressed during the presentation.

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

Reviewer 1:

The reviewer commented that, given the exploratory nature of this project, the goal was rather broad in nature, citing the entire goal as to identify alternative hard ferromagnetic materials which do not contain rare-earth elements and are relevant to permanent magnet (PM) motor technology. The team is making good progress towards what is clearly a long-term goal. The reviewer felt the team was producing useful findings, both in terms of the physical metallurgy of these materials, as well as their processing. The reviewer concluded that promising chemical systems have been identified for further study.

Reviewer 2:

The reviewer judged that the presentation clearly showed the progress being made on different alloy systems. The end goal for the program seems to be to have evaluated numerous categories of potential PM materials without a particular emphasis on perfecting a single system. The reviewer thought this might be considered a strength (wide range of potential material) and a weakness (if the conclusions do not move us significantly toward a more mature tollgate). The reviewer was not completely clear whether there is a planned downselection of promising PM systems, although it would be relevant when the evaluations cover a wide range of conceptual materials.

Reviewer 3:

The reviewer felt that good progress was being made towards program goals; however, significant work remains before viable replacements for rare earth-based magnets are developed.

Reviewer 4:

The reviewer deemed technical accomplishments to be adequate. However, the reviewer was concerned that after almost four years into the project, the focus is on the material development. Further, it was not clear whether the hafnium-based material would be cost-effective material. A simple cost analysis would provide some indications. The reviewer reported that substituting zirconium for hafnium has been suggested, but no plans for conducting that work are presented.

Reviewer 5:

The reviewer relayed that this project has been ongoing since 2009 and is slated to end in 2015. During that time the project team identified several new ferromagnetic compounds and is in the process of characterizing their properties. The reviewer thought it would be useful for the PIs to compare the current level of performance against automotive needs and state-of-art magnet technology.

Reviewer 6:
The reviewer revealed that a new material has been identified and initially characterized that has the potential to provide desirable magnetic parameters comparable to and possibly in the long run competitive with rare earth magnets. The reviewer thought that the melt spun technique appeared fruitful, and that follow-on work with zirconium would be a reasonable next step. The reviewer reported that the efforts with phosphides (listed as FY 2013 milestone) were not adequately addressed in presentation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer concluded that collaboration has provided an efficient means to achieving technical progress and has resulted in peer-reviewed publication.

Reviewer 2:
The reviewer expressed that the bulk of the work is clearly ORNL-centric (collaborations with the University of Tennessee are somewhat inevitable); but that complementary studies carried out by other groups (Georgia Institute of Technology) appear to support the work.

Reviewer 3:
The reviewer reported that there was collaboration with University of Tennessee and Georgia Tech Research Institute (GTRI) and coordination with the Ames Lab effort.

Reviewer 4:
The reviewer stated that current collaborators and partners are involved in the technical aspects of the project. The reviewer suggested that it may be useful to establish collaborations with electric motor manufacturer to gain insights into feasibility of the material being developed as a commercial product.

Reviewer 5:
The reviewer commented that, because of its nature, this project has limited collaboration with industry or supply chain. The reviewer commented primarily a fundamental research project with collaboration limited to other FFRDC and academia (i.e., Ames and universities).

Reviewer 6:
The reviewer observed that there were minimal collaborations, primarily within the ORNL/University of Tennessee complex. The reviewer was unclear on the role that Georgia Tech plays.

Reviewer 7:
The reviewer reported that, as the presenter noted, there is significant work being done on non-rare-earth magnets. The reviewer listed this work as including ARPA-E REACT, U.S. DRIVE (U.S. Driving Research and Innovation for Vehicle Efficiency and Energy sustainability), BREM, etc. In particular, ARPA-E is funding work at Northeastern University on stabilized $L1_0$ phases (i.e., http://arpa-e.energy.gov/?q=arpa-e-projects/iron-nickel-based-supermagnets). The reviewer commented that there should be greater collaboration in this work.

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

Reviewer 1:
The reviewer saw that the team has clear directions for future work. the reviewer listed cost-reduction of the Hf-based chemistries by substitution of Zr for Hf; enhancing the performance of the Hf-based chemistries through improved processing; and further exploration of stabilized $L1_0$ iron-nickel intermetallics. These directions address the barriers and limitations of past work.

Reviewer 2:

The reviewer deemed the plans for Hf-Co-B to be well laid out and reasonable, as are the Fe-Pd-Ni efforts. The reviewer noted, however, that phosphide development work was not well covered in the presentation.

Reviewer 3:

It was clear to the reviewer that use of hafnium-based compounds will be quite expensive; hence substitution of hafnium with other elements would be required. The reviewer reported that one suggestion made was for use of zirconium, however, there was no mention of synthesizing and evaluation of zirconium-based compounds. Further, the reviewer relayed that there was limited reference to how the work being conducted as part of the project will transition into a commercial product.

Reviewer 4:

The reviewer found that the path to the next step was not entirely clear, although it all falls under the new materials for PMs category. Maybe this could use a bit more emphasis, but the step from one materials type to the next does not always seem to build upon past discovery. The reviewer asked if the next up would be studies on phosphides, and wondered if this was natural extension of the Hf-Co-B work. Also, the reviewer questioned what of that work was based upon $L1_0$ or earlier iron-based ferromagnetic work.

Reviewer 5:

The reviewer reported that the 6.7 MgO max energy product shown, not clear how higher-energy products would be achieved. Much work remains.

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

Reviewer 1:

The reviewer declared that this is a tremendously relevant topic. The importance to the nation is hard to exaggerate. The reviewer sees reducing dependence on rare earths as a national challenge and on the same level as reducing dependence on petroleum. Although this is clearly not the only work DOE is doing in this regard, the reviewer thought the type of long-term exploratory work embodied by this project is highly important.

Reviewer 2:

The reviewer considered that the main principle of the study (i.e., reducing the inherent cost of electric propulsion systems) certainly supports the objectives. The development of efficient electrical propulsion systems naturally reduces the dependency on petroleum, while the goal of reducing the dependency on rare earth elements provides an even more important contribution, thereby making electric propulsion an affordable alternative to ICEs.

Reviewer 3:

The reviewer reported that the project's goal is to reduce costs for the permanent magnets by using non-rare earth materials, which is bound to reduce the costs and meet DOE cost targets for power electronics for 2020. The reviewer predicted that if the cost target is met, then large-scale viability of HEVs and EVs will be reasonable, which will in turn lead to significant petroleum displacement.

Reviewer 4:

The reviewer found elimination of rare earth materials to be critical to efficient and low cost electric drives for EV/hybrid applications.

Reviewer 5:

The reviewer stated that the project supports goals of lower-cost EV 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 deemed that, as new magnet materials are critical to vehicle electrification efforts, additional resources should be allocated to speed the development of these materials.

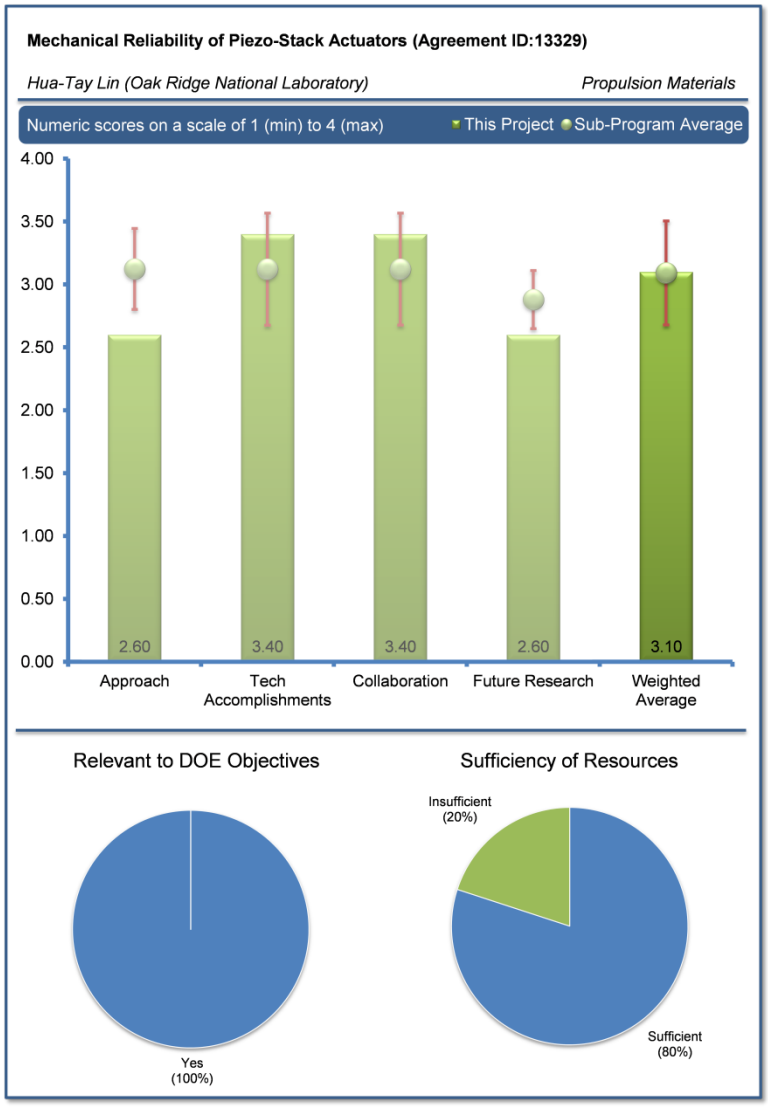
Reviewer 2:
The reviewer saw that the team appeared to be functioning well at current resource levels, but given the importance of this work, suggested that resource levels should be increased, and greater integration with other DOE efforts should be encouraged.

Reviewer 3:
The reviewer commented that ORNL and its collaborators appeared to have sufficient resources in terms of highly qualified personnel, laboratories and equipment.

Reviewer 4:
The reviewer judged resources in terms on manpower and facilities to be adequate for the project.

Reviewer 5:
The reviewer found that the resources were sufficient based upon a confidence that the research group knows what it will need - the focus shifts significantly enough for future endeavors that it is difficult for an outside reviewer to make a direct judgment.

Mechanical Reliability of Piezo-Stack Actuators (Agreement ID:13329): Hua-Tay Lin (Oak Ridge National Laboratory) - pm046



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer characterized the approach as the typical approach of make, test, evaluate and improve the material to address any failures.

Reviewer 2:

The reviewer asked if material constitutive models and failure mechanisms were being developed from experimental test for use in finite element analysis (FEA) design efforts. The reviewer reported thorough experimental testing to characterize material behavior under various conditions in order to prioritize material selection. The reviewer wondered if the results being obtained were being transferred to FEA to complete design optimization by project completion.

Reviewer 3:

The reviewer reflected that the fifth year of a six-year project is rather late in the program to be developing new techniques, and the PIs are reporting on the development of lab techniques to characterize high temperature properties. The reviewer thought that it would have been more prudent for the project team to wrap up previous studies and propose a new project. The reviewer asked what the rationale was for studying the effect of humidity on performance instead of fuel vapors and noted that these elements will operate in a fuel injector where they will be exposed to fuel vapors.

Reviewer 4:

The reviewer felt that the technical barriers were not well-defined. The project focused on characterizing the material and there is little information on the requirements to be reached to reach the goal of 2800 bar fuel injection pressures.

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

Reviewer 1:

The reviewer commented that technical progress was good, but suggested that since this work seems to fall under the label of Product Improvement, perhaps future work should be conducted under a Work for Others (WFO) CRADA where the industrial partners pay for the use of ORNL capabilities.

Reviewer 2:
The reviewer found that the progress was good compared to the goals, and that the project was being executed according to the plan. The main objective is to characterize the PZT (lead zirconate titanate) materials. It was not clear to the reviewer how the results of this project contribute to the overall mentioned goal of 55% engine thermal efficiency. It was difficult for the reviewer to evaluate to what extent barriers were/need to be overcome.

Reviewer 3:
The reviewer thought there were good experiments conducted to understand material behavior and aging effects. Several years into a project it would be expected to have material property requirements understood when evaluating and reporting experimental results. The reviewer wondered if target property requirements have been established for heavy-duty (HD) engine fuel injectors. The reviewer asked if the materials being investigating were showing promise for meeting objectives or not.

Reviewer 4:
The reviewer revealed that progress during the prior years was not reported and thus it was difficult to judge overall progress that the project was making on identifying the impact of environmental factors on performance.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that since this work is being conducted under a CRADA, collaboration appeared to be excellent.

Reviewer 2:
The reviewer agreed that there was excellent commitment from industry and a material supplier.

Reviewer 3:
The reviewer saw good collaboration with fuel injector and engine OEMs.

Reviewer 4:
The reviewer remarked that there was a good cooperation with industry, and foresaw a clear path to implementation.

Reviewer 5:
The reviewer found there to be equal funding with Cummins, but found unclear what Cummins' contributions to the project were to date.

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

Reviewer 1:
The reviewer reasoned it likely that the barriers would be overcome, especially since the goal is to optimize the component design through probabilistic component design.

Reviewer 2:
The reviewer judged that future research clearly defined future experimental plans to further characterize material. It was not as clear to the reviewer how knowledge gained is being transferred to design and development of target applications, leading the reviewer to ask if the fuel injector concept using these materials has overcome the barriers.

Reviewer 3:
The reviewer recommended that future work of this kind should be conducted under a WFO CRADA.

Reviewer 4:
It appeared to the reviewer that the future activities would not be achieved with the current budget constraints being imposed on the PM program.

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

Reviewer 1:
The reviewer discussed that a higher injection pressure and closer control of the injection cycle will result in reduced fuel consumption, and confirmed that this project will be an enabler for this.

Reviewer 2:
The reviewer reasoned that improving heavy duty injectors does support the overall DOE objective of saving petroleum.

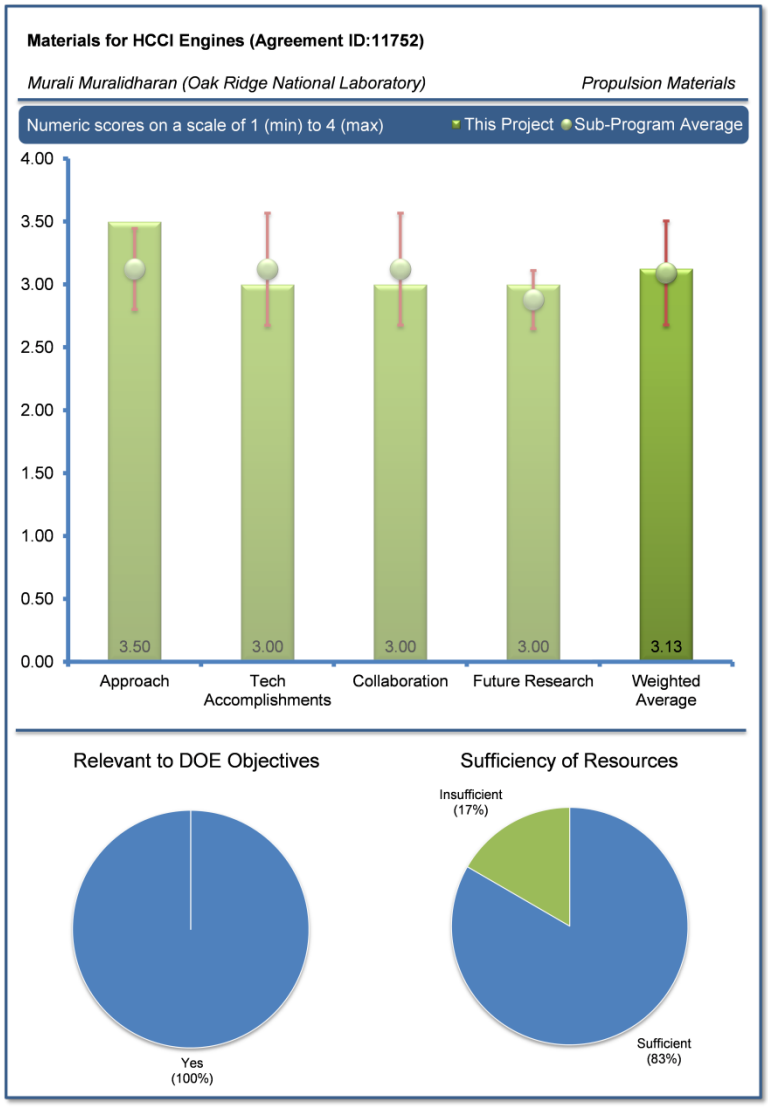
Reviewer 3:
The reviewer agreed that fuel injector technology is important for achieving fuel economy and emission requirements.

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

Reviewer 1:
It appeared to the reviewer that resources were adequate to achieve the milestones in a timely manner, although there was no guarantee that the overall performance of the materials in-situ would be improved.

Reviewer 2:
The reviewer agreed that the budget is in line with the provided results.

Materials for HCCI Engines (Agreement ID:11752): Murali Muralidharan (Oak Ridge National Laboratory) - pm047



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer commented this project exhibited what National Labs do best, which is research using advanced methods on fundamental engineering problems.

Reviewer 2:

The reviewer commented that to start with integrated computational materials engineering (ICME) was a good approach to have guidance on the potential composition of the new alloys. This was followed by a limited number of alloys produced for further evaluation.

Reviewer 3:

The reviewer reported that technical barriers that were considered have been well defined, but noted that all technical barriers have not been fully investigated, such as temperature aging and corrosion.

Reviewer 4:

The reviewer relayed that there has been alloy development using first principles and ICME, and recommended that the trial should be recorded so that future efforts can be improved upon. Even though the effort is based on ICME, many trials were needed. The reviewer thought it would be useful if some information or estimate could be provided on what would have been the physical efforts, if the ICME route is not followed.

Reviewer 5:

The reviewer asserted that the goal of this project is very clearly defined on Slide 6 [i.e., improve fatigue life at a temperature of 870°C, 35 kips per square inch (ksi) stress while maintaining the lowest possible cost (lowest Ni additions)]. The reviewer thought there was a solid approach to meeting this goal; by identifying a target microstructure and using thermodynamic/kinetic modeling to identify possible routes to achieve this microstructure, then making samples and performing microstructural characterization/fatigue testing.

However, the reviewer also commented that this goal was very narrow. There are many properties that are needed in an exhaust valve, of which fatigue life at 870°C and 35 ksi stress is only one. The reviewer recommended that creep, among other phenomena, also needs to be considered in order to meet the broader objective of this project, as stated on Slide 3 (i.e., develop cost-effective exhaust valve materials suitable for operating at higher temperatures [870°C versus current 760°C] for use in advanced engine concepts).

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

Reviewer 1:
The reviewer reported that this project has successfully developed a family of alloy with higher strength (30-80%) and lower cost (25-40%) than the current commercially-used alloy, in a relatively short period of time (seven years). The reviewer considered this a significant achievement, and demonstration of the validity of the approach.

The reviewer commented that the limitations of these findings (i.e., properties and cost depend on processing, which was not optimized in this project) were also clearly identified by the presenter.

Reviewer 2:
The reviewer remarked that the alloys have been assessed as worthwhile for IP (intellectual property) protection, which itself is an achievement, even if most of the time compositions cannot be effectively protected. The reviewer reported that the work has been completed on basic assessment, but thought more experiments, such as corrosion at high temperature, need to be carried out.

Reviewer 3:
The reviewer relayed that materials with improved properties have been successfully identified. Tradeoff studies have been conducted to improve ductility with minimal loss in strength. It appeared to the reviewer that materials were an improvement over baseline alloy. Fatigue properties at higher stress levels could be an issue for higher performance engines.

Reviewer 4:
The reviewer found that the project produced a number of potential lower cost alloys as compared to the current material. Although there was a significant improvement in fatigue strength at 870˚C it was not clear to the reviewer if this was sufficient for application of this material in an engine valve application. Next to fatigue strength thermal conductivity at the targeted temperature is an important material characteristic. Although the reviewer expected improvements based on composition, an indicative measurement would be supportive.

Reviewer 5:
The reviewer stated the project had test results demonstrating goals, and suggested that as a next step need a commercial partner.

Reviewer 6:
The reviewer called the project a concluding line of research.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer judged there to be a good collaboration in the supply chain of this material, and noted that there was no collaboration with other institutions or universities.

Reviewer 2:
The reviewer reported that there were some discussions with potential alloy manufacturers, but no indication of any significant end user interest. The reviewer noted possible participation if alloy is available in quantity at low cost.

Reviewer 3:
The reviewer stated that there was involvement from material and valve manufacturers. The reviewer thought that it would be good to directly involve engine manufacturer to consider actual loading conditions a valve experiences during operations and definition of all property requirements in order to satisfy all functional requirements.

Reviewer 4:
The reviewer relayed that targets had been discussed with a manufacturer.

Reviewer 5:
The reviewer commented that greater collaboration from Eaton in better identifying the properties needed for an exhaust valve would be valuable. The reviewer thought the stated goal defines too narrowly the requirements for an exhaust valve.

Reviewer 6:
The reviewer felt that, even though discussion was carried out with many material suppliers, not many were involved, the work was very basic and no commercial interest was driving this project.

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

Reviewer 1:
The reviewer declared that there is a need to get a more comprehensive understanding of the fatigue curve shape for the high potential alloy candidates.

Reviewer 2:
The reviewer noted that the project is close to its finalization, and that remaining activities are well described and planned.

Reviewer 3:
The reviewer felt that it was not obvious how the plan was followed, but the method seemed to work. The project is almost finalized (99%).

Reviewer 4:
The reviewer called this a concluding project.

Reviewer 5:
The reviewer relayed that no new work is proposed, and at the end of funding for the project.

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

Reviewer 1:
The reviewer advised that enhancing the temperature of operation in powertrain will improve the fuel efficiency, which is one of the objectives of VTO.

Reviewer 2:
The reviewer saw that the developed material would allow higher temperatures in the combustion chamber, and this will lead to higher thermal efficiency of the engine and will reduce fuel consumption.

Reviewer 3:
The reviewer observed that the project meets a clear industry need. As exhaust temperatures continue to increase, industry will need materials that can withstand the higher temperatures, without incurring an unacceptable cost penalty. The reviewer felt this project was a good first step, although there is clearly much more work to do.

Reviewer 4:
The reviewer observed an enabler (among many others) for engines with higher efficiencies.

Reviewer 5:
The reviewer stated that engine valve materials are a known constraint to cost effectively achieving high performance and efficient engines.

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

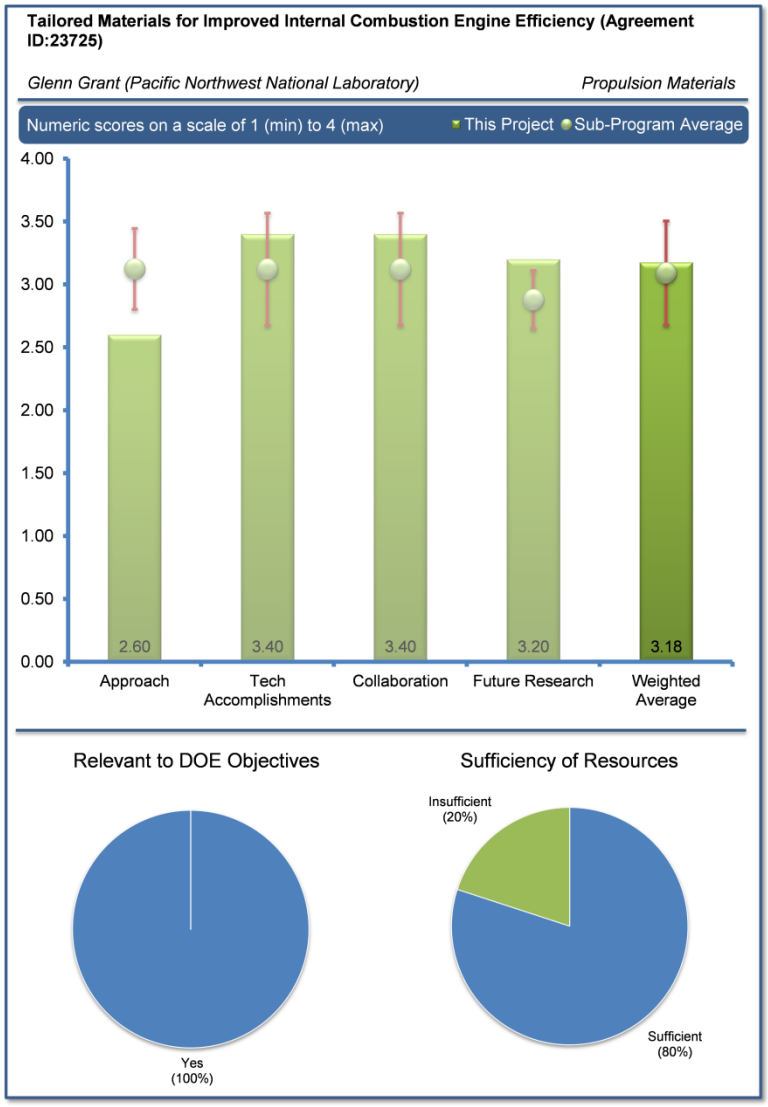
Reviewer 1:
The project appeared to the reviewer to be complete and not receiving funding, but testing is ongoing.

Reviewer 2:
The reviewer concluded that the project is finished based on the provided budget, and that results were achieved.

Reviewer 3:
The resources appeared to be sufficient to achieve the fairly limited goals of this project. However, the project could have benefited from greater resources, in order to address the broader topic of developing suitable alloys for HCCI applications. Hopefully, this project will continue in some form or another.

Reviewer 4:
The reviewer could not judge the appropriateness of the resources.

Tailored Materials for Improved Internal Combustion Engine Efficiency (Agreement ID:23725): Glenn Grant (Pacific Northwest National Laboratory) - pm048



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer thought that this seemed to be a cost-effective technology with many different possible applications. Due to that it is good to see the close cooperation with GM.

Reviewer 2:

The reviewer expressed that the approach for improving the strength of Al alloys was a straight forward approach and will have the potential to overcome the technical barriers. However, the reviewer found that the approach for the second task was not clear. FSW is a process to optimize cast microstructures. In this case it looked as if an attempt is made to optimize the structure of forged material. The reviewer relayed that during the presentation it was confirmed that this has a little change of success and that the focus should be on iron cast crankshafts. The reviewer advised that, for this, it is necessary to do tests on cast iron material and not on rolled material.

Reviewer 3:

The reviewer thought the title was not representative of the project objectives. The work is to improve properties of surfaces through FSP. Two different materials are being processed to change the surface micro structure to improve high temperature stability or fatigue resistance.

Reviewer 4:

The reviewer felt that the objective of this project was rather loosely defined: employ FSP to improve the performance of engine components. The reviewer pronounced that more specific and measurable goals would help to make this project more successful.

For Task 1 (FSP of Al castings), the goal of a 10% improvement in room-temperature fatigue performance seemed to the reviewer to be excessively modest, especially given Jana's previous (2010) work showing a 5x improvement for investment-cast F357. The reviewer did not see any other quantitative goals. Thermal fatigue improvement, which is a major part of Task 1, did not have its own subtask assigned. Creep-fatigue was discussed, but there did not appear to be a clear plan of how creep-fatigue will be addressed.

The reviewer observed from the reviewer-only slides that Task 2 (FSP of steel forgings/castings) had not yet started, and needed to be worked out in greater detail to determine whether it was even worth pursuing. The reviewer thought that FSP was unlikely to provide any measurable benefit for forged crankshafts.

Given that there has been a significant body of work on modeling of microstructural evolution during FSP, the reviewer was disappointed that this project apparently did not include a modeling component. The approach so far appeared to the reviewer to be purely experimental. Also, this project did not appear to contain any fundamental work to advance understanding of FSP in general. The reviewer felt that this limits the broader value of the work.

The reviewer suggested that it would be beneficial to re-focus this project on FSP of Al castings only (i.e., eliminate Task 2), and develop a more focused plan around Task 1, incorporating clearly-defined quantitative performance improvement goals, better understanding of fundamental mechanisms, and computational modeling.

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

Reviewer 1:
The reviewer observed that the progress in Task 1 was very good, and that deliverables were met. The process was developed and showed good results for the microscopic structure of the material. The reviewer noted that in Task 2 no progress has been reported, but wondered if this could be in line with the planning, since no Gant chart was provided.

Reviewer 2:
The reviewer advised that the project was still waiting for results on hot engine components.

Reviewer 3:
The reviewer reported that the effect of stir processing on the micro structural change and improved properties were discussed. As the Al alloy is stir processed a fine grained structure is obtained, which will have improved crack arresting capability. However, the reviewer explained that fine-grained structure is known to suffer from creep and long-term exposure to high temperatures may accelerate this failure mechanism. Also, the interface between the FSP and base metal will be weak point at high temperatures. The reviewer thought that these effects need to be addressed before commercialization is tried.

Reviewer 4:
The reviewer was concerned that the project is only 30-40% complete, given that nearly 60% of the project time has passed. Task 2 has not been started yet, and key components of Task 1 are still not clearly defined. The reviewer recommended that the goals and timeline for this project should be re-evaluated.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed very good cooperation with GM.

Reviewer 2:
The reviewer saw definite manufacturing and production incorporation interest, and thought there was potential for transition to end users.

Reviewer 3:
The reviewer found there to be a good collaboration between industry, PNNL, and the University of North Texas. The cooperation could be called outstanding if the goals for Task 2 were clearer.

Reviewer 4:
The reviewer thought the corporate partner (GM) appeared to be providing solid support for this project. However, the reviewer wondered if the apparent lack of focus in this project is a result of GM having unclear expectations. It was difficult for the reviewer to determine.

Reviewer 5:
The reviewer reported that an OEM is actively involved and agreed to conduct field trials on components. This reviewer felt this was quite significant as it makes the technology transfer very effective.

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

Reviewer 1:
The reviewer found that future plans are in line with the outcome of previous activities.

Reviewer 2:
The reviewer thought that addressing hot engine parts is next step.

Reviewer 3:
The reviewer relayed that the effort will move on the steel structure and fatigue resistance of the stir processed surface. However, the reviewer maintained that the effect of fine grain structure on the creep performance needs to be evaluated for Al alloys; also the interface or process affected zone need to be characterized.

Reviewer 4:
The reviewer remarked that future work was not well-defined because the goals of the project as a whole are not well-defined. The reviewer concluded that the goals and timeline for this project should be re-evaluated.

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

Reviewer 1:
The reviewer felt that this project is potentially of significant value in enabling the use of lightweight materials and advanced combustion technologies.

Reviewer 2:
The reviewer agreed that, yes, it is one enabler among many for higher engine efficiency.

Reviewer 3:
The reviewer discussed that improved high temperature strength in cylinder heads will enable higher thermal efficiency of the engine.

Reviewer 4:
The reviewer reported that selective reinforcement or modification of surface is an optimized process to use current materials in more demanding applications. The reviewer saw that this could reduce the cost of developing new materials and make the process economically viable.

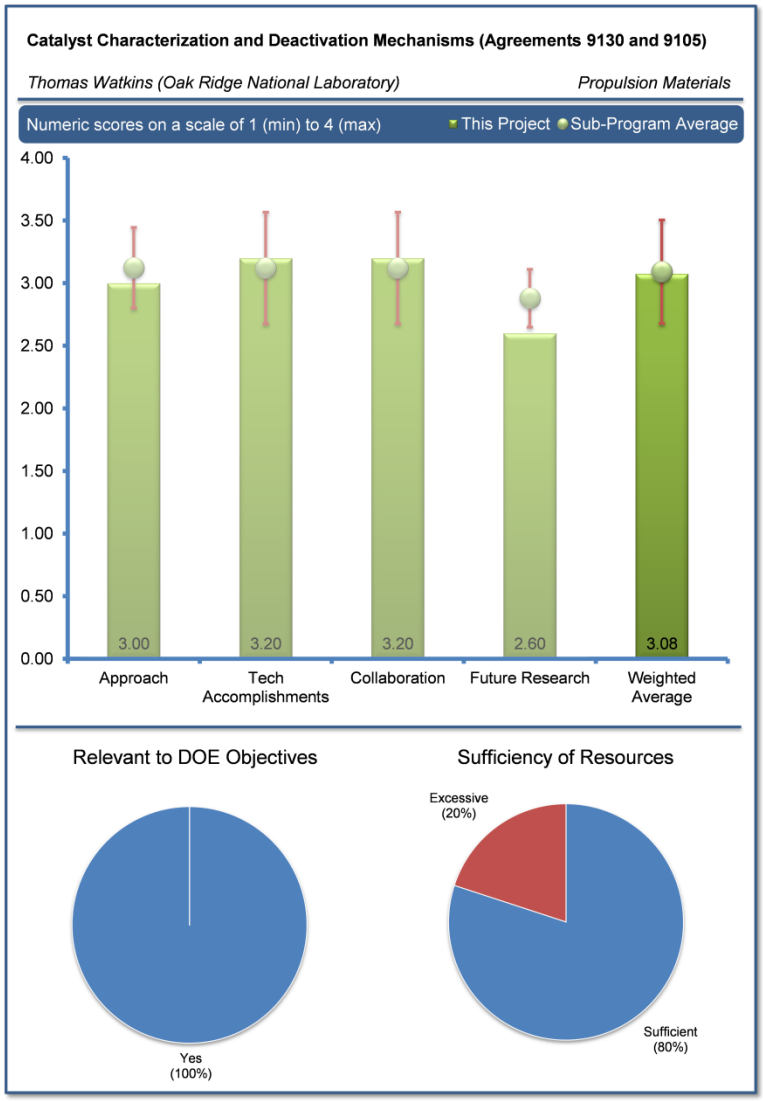
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer reasoned that, given the importance of this project and the slow progress, more resources are needed. Computational resources, in particular, would be of value to this project.

Reviewer 2:
The reviewer felt that simple equipment was used so resources are sufficient.

Reviewer 3:
The reviewer said that the budget is sufficient to reach the goals.

Catalyst Characterization and Deactivation Mechanisms (Agreements 9130 and 9105): Thomas Watkins (Oak Ridge National Laboratory) - pm049



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer thought the approach to the 9130 project was good, and gave it a rating of three. The reviewer felt that a better understanding of benefit and limitation of ammonia oxidation (AMOX) catalyst was important to develop AT control mechanism and maximize long-term nitrogen oxide (NO_x) efficiency over selective catalytic reduction (SCR); however, selecting platinum (Pt) as an AMOX catalyst was not a good approach as the particular metal can convert ammonia (NH_3) into NO_x. The reviewer added that not having a detailed performance measurement plan in the approach was the weak point.

The reviewer thought the approach to the 9105 project was outstanding, and gave it a rating of four. The reviewer felt the approach using a gas-reaction holder for in-situ transmission electron microscopy (TEM) was very unique and the presented technique could provide features that others could not investigate automotive catalytic materials with during the thermal and chemical deactivation.

Reviewer 2:

The reviewer stated that the application of methodologies was good.

Reviewer 3:

The reviewer disclosed that this is a very mature (more than 10 years) project focused on advanced characterization techniques of catalysts most recently employing in situ heating and gas flow capabilities. As exhaust temperatures change, there is value in providing the ability perform characterization at operating temperatures with experimental gaseous mixtures. This project appeared to the reviewer to be more service oriented than research oriented. ORNL is providing a valuable resource for collaborators interested in testing a variety of potential catalysts.

Reviewer 4:

It was difficult for the reviewer to find fault with the development of advanced techniques that provide a clearer understanding of catalyst response at atomistic length scales.

Reviewer 5:

The reviewer reported that the project proposed to experimentally characterize AMOX catalysts and SCR materials in various states of use from fresh to aged. The characterization involves microscopy and elemental analysis. The reviewer observed that results were shown yet no clear results were articulated. Pt particle growth in AMOX catalyst with increasing temperature is known and expected. The reviewer was left wondering what new insights or conclusions had been reached; likewise, with the elemental analysis, the reviewer asked what insight or actionable conclusions could be reached from the knowledge of non-homogeneous distributions of Zr and Cu.

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

Reviewer 1:

For the 9130 project, the reviewer gave a rating of two. The reviewer commented that accomplishments were very disappointing, producing no new information on Pt degradation under hydrothermal aging conditions. The reviewer reported that there are hundreds of references out in the public domain about how Pt grows under high temperature (greater than 700˚C). Slide 10 does not show any information; zirconium dioxide (ZrO_2) may be from the binder for washcoat process. Also, the reviewer wondered if BASF is involved in this project, because the PIs cited a patent filed by BASF. The reviewer also noted that in-situ X-ray diffraction (XRD) data is also from a reference done by other group.

The reviewer thought the progress on the 9105 project was outstanding, and gave it a rating of four. The reviewer thought that it was a brilliant idea to have a microscale gas channel in vacuumed chamber for the in-situ work. The reviewer was looking forward to seeing more progress next year.

Reviewer 2:

The reviewer gave progress a positive grade, but thought that it may seem a bit harsh based upon the development and employment of new technology to provide advanced characterization capabilities. An alternate general synopsis might be summarized as follows: The group collaborated on a new characterization technique, and then utilized it. The reviewer felt that without an in-depth analysis of the justification or hypotheses concerning the observed behavior and an elucidation of these hypotheses on future work, some room for improvement of an otherwise very successful program exists and an outstanding grade is not necessarily warranted. The reviewer concluded that the work is impressive and the goal is catalyst characterization, but some employment of this clear expertise beyond what was observed for a particular set of conditions would be an improvement.

Reviewer 3:

The reviewer stated that development of advanced characterization capabilities and use of instrumentation for characterization of new materials has enabled improved understanding for collaborators.

Reviewer 4:

The reviewer thought that the applications seemed to be less at the forefront of the technology. These catalysts are out there in use, leading the reviewer to question whether the PIs should be addressing new generations, or new problem areas.

Reviewer 5:

The reviewer observed technical accomplishments related to characterization, but noted that characterization, in isolation, is of limited value. Instead, characterization coupled with performance data and/or parametric studies would help answer critical questions of relevance to the broader community. The reviewer felt the project needed to set clear objectives as to the critical questions being answered, how the test is designed to get those answers, and then a concise presentation of the results. One of these projects has been ongoing for 11 years. The reviewer asked what the overall mission has been, and where the timelines, milestones, decision points were.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed that collaboration and support of industry (Ford, Cummins) appeared to be very useful. Collaboration with Protochips to advance capabilities of the electron microscope has also been fruitful, the reviewer noted.

Reviewer 2:
The reviewer believed that collaboration must be acceptable from Cummins side.

Reviewer 3:
The reviewer relayed that the role of Cummins appeared to be assisting in establishing specific parameters for observation, and that the developments with Protochips were a significant accomplishment.

Reviewer 4:
The reviewer felt that both branches of the project showed fair collaboration, and gave them a rating of two. For the 9130 project, it was not clear to the reviewer what the contribution from Cummins was. The reviewer wondered if there any vehicle level achievement available, and noted that it was not necessarily a set of data if it is proprietary information. For the 9104 project, it would have been great if the newly developed technique was available for other groups such as fuels and emission groups at ORNL.

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

Reviewer 1:
The reviewer saw that the future work seems to follow the same (or similar) established path, with an eye toward improving existing test techniques and adding new materials to the test matrix.

Reviewer 2:
The reviewer reported that proposed future work is to continue along the lines of characterization of materials for collaborators.

Reviewer 3:
The reviewer felt that both branches of the project proposed good future research, and gave them a rating of three. For the 9130 project, the proposed future work was very well listed; however, the reviewer noted those are all work to be done at ORNL not Cummins. For the 9105 project, the future scope was not very clear about what will be the next scope in material characterization, although it is well explained on the hardware side.

Reviewer 4:
The reviewer felt that this should be re-visited in terms of whether these resources might be better employed in other projects rather than on this selective CRADA.

Reviewer 5:
The reviewer questioned why these projects would be renewed; and wondered what the ultimate objectives and outcomes would be. The reviewer was extremely concerned at the presenters comment that the project has no metrics or targets. The reviewer could not see how the DOE mission was being furthered, or what value was being added.

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

Reviewer 1:
The reviewer remarked that both projects support the DOE effort on optimizing fuel-efficient vehicle technologies.

Reviewer 2:
The reviewer stated that characterization of catalysts at realistic gas temperatures and pressures would provide valuable information for development of new catalysts.

Reviewer 3:
The reviewer revealed that although the research is fundamental in nature, it does lend credibility to developments in clean diesel technology, which provides reduced petroleum consumption if deployed on larger scales relative to gasoline combustion engines.

Reviewer 4:
The reviewer found the argument that this research supports DOE goals to be a bit of a stretch, and pointed out that automotive emissions issues involve fuels and fuels may be something other than petroleum.

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

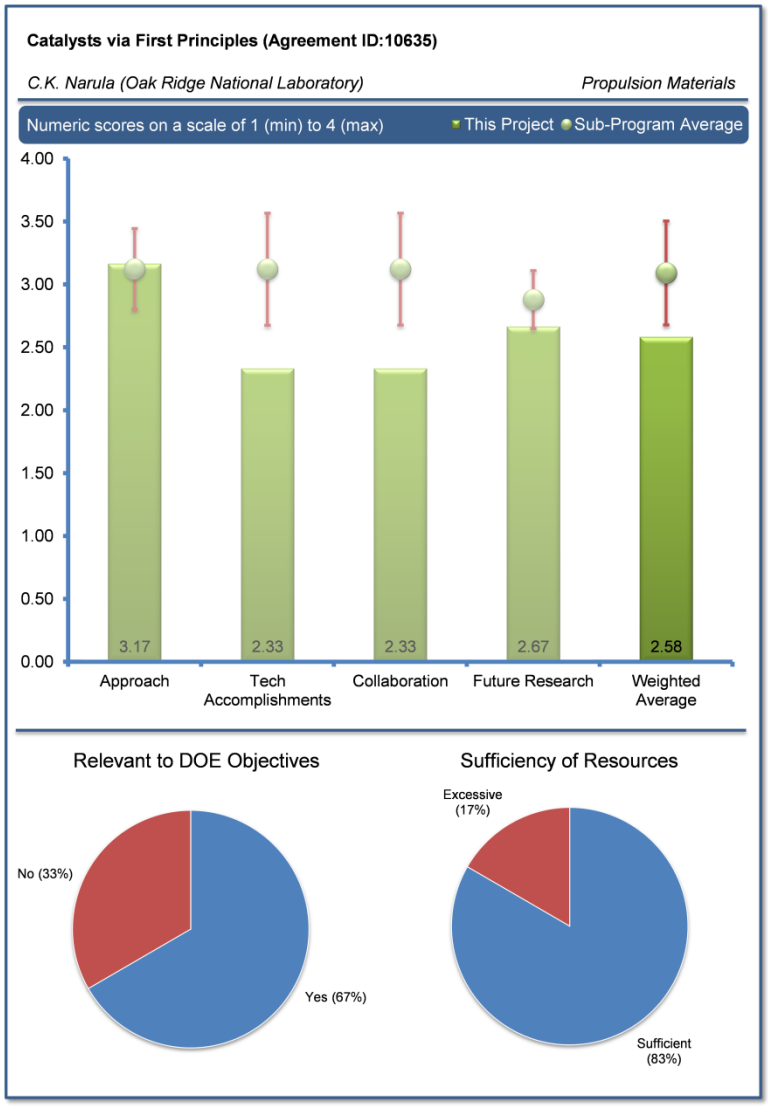
Reviewer 1:
The reviewer said the future work appeared to be a continue-as-before approach for the most part, involving a wider range of catalyst conditions.

Reviewer 2:
The reviewer judged resources on both projects to be sufficient and well-allocated, and noted that the progress for the project 9130 is not sufficient compared to the level of funding the project received. The project 9105 may need more funding to improve and standardize the unique in-situ characterization technique.

Reviewer 3:
It appeared to the reviewer that this project has been adequately funded by government and industrial sources for an extended period of time. It is not clear if future funds will be adequate to continue to cover system development and characterization activities.

Reviewer 4:
The reviewer recommended that re-deployment should be considered.

Catalysts via First Principles (Agreement ID:10635): C.K. Narula (Oak Ridge National Laboratory) - pm050



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer thought that there was a very well-defined effort on both theoretical and experimental studies. The PI was very knowledgeable on the fundamental catalysis.

Reviewer 2:

The reviewer judged that the project had a well-conceived blend of modeling and experiment.

Reviewer 3:

The reviewer stated that the project approach utilized a blend of first principles modeling with experiments and characterization.

Reviewer 4:

While the objectives seemed to the reviewer to be well-defined, the barriers being presented on Slide 3 did not seem to have any particular focus on first-principles advantages to practical research in this field. Slide 5, however, accomplishes this specific focus in very clear fashion. The reviewer concluded that the approach was well-established and the utility of simulation-based atomistic selection of ideal catalysts is a significant body of work.

Reviewer 5:

The reviewer reported that this project is apparently a perennial project. The reviewer expressed that Pt on alumina is old work to be expending resources upon. Copper chabazite is already in commercial use, and the modeling link-up is tenuous at best.

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

Reviewer 1:

The reviewer thought the work on single atom oxidation of CO (carbon monoxide) and NO (nitric oxide) was interesting, and that the work on low temperature CuFe zeolites was timely and relevant.

Reviewer 2:

The reviewer saw promising progress so far, and declared that engine testing is warranted based on prior results.

Reviewer 3:
The reviewer reported that addition of iron for CuFe-ZSM-5 zeolite catalyst appears to meet low temperature catalyst goal. An 80% NO conversion at 150°C was achieved. The reviewer stated that understanding was gained that single Pt atoms are active catalysts for CO but not for NO_x.

Reviewer 4:
The reviewer relayed that, although it was hard to judge the progress without the previous work available, this project seemed to have stayed focused on identifying the active sites for low temperature emission control.

Reviewer 5:
The reviewer was impressed by the overall development of the calculations-based selection process for effective catalyst reactions. However, the reviewer found the work centered on single Pt atoms to be somewhat confusing, and stressed that this does not mean that it lacks accuracy. The reviewer queried whether it is being suggested that a high-angle annular dark-field (HAADF) detector is imaging single atoms, and would like to know by what mechanism (e.g., simple scattering). The reviewer stated that a Bragg condition would certainly not be satisfied. Supporting evidence of this phenomenon would be helpful in cementing this observation, even if simply limited to an atom count based upon the estimated imaged volume to see if the atomic fraction of Pt matches the observations. The reviewer concluded that even minor clustering could be discounted if the atom fraction matches reasonably well.

Reviewer 6:
The reviewer felt that these were not very distinguished results. Pt crystal growth is well known and old knowledge.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer saw that collaboration with industry (John Deere) is good.

Reviewer 2:
The reviewer felt that the collaboration efforts with John Deere were not entirely clear outside of off-road degreening and testing protocols, and asked if they provided conditions alone or actual engine testing, or if the entirety of engine testing was to be undertaken later in FY 2013.

Reviewer 3:
The reviewer noted that John Deere was to provide engine testing support, but wondered who was providing automotive engine testing support for CO catalyst development.

Reviewer 4:
The reviewer observed that the project involved one heavy-duty engine manufacturer (John Deere), and that there could be a synergy if more light-duty OEMs were involved, especially for low temperature challenges.

Reviewer 5:
The reviewer thought that the project would have greatly benefited from additional partners, and recommended that the interest from Chrysler and/or Cummins be actively pursued.

Reviewer 6:
The reviewer found that collaboration was not memorable as described.

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

Reviewer 1:
The reviewer thought that future research was very well-defined; however, it would have been excellent if a catalyst supplier or their samples can be involved for the future plan.

Reviewer 2:
The reviewer reported that activities for next year appeared to be consistent and reasonable.

Reviewer 3:
The reviewer felt thought that developments in calculation- or simulation-based materials selection in almost every sense have widespread future applications. However, the reviewer also cautioned that the future research being proposed does not go into nearly enough detail to take credit for the progress to date.

Reviewer 4:
The reviewer asked if there are leading contenders to replace Pd as a lower-cost solution for Pt stabilization.

Reviewer 5:
The reviewer concluded that engine testing is a logical and critical next step.

Reviewer 6:
The reviewer recommended that this project be re-evaluated.

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

Reviewer 1:
The reviewer found that this project would support the low temperature after treatment activity that DOE emphasizes for harmonizing future advanced combustion systems.

Reviewer 2:
The reviewer thought that the direct application may not be immediately clear (presently focused on off-road applications), but reasoned by inference that the developments have much more widespread application.

Reviewer 3:
The reviewer felt thought this project seemed entirely focused on emissions reduction and not on petroleum displacement. The reviewer did not see any linkage presented on engine efficiency.

Reviewer 4:
The reviewer stated the project was reducing emissions of high-performance gasoline and diesel engines.

Reviewer 5:
The reviewer said that it was not very evident if the program supported DOE goals.

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

Reviewer 1:
The reviewer found that the project was very well planned and allocated resource and activities.

Reviewer 2:
The reviewer reported that no specific barriers to progress seemed to exist to meet the objectives.

Reviewer 3:

The reviewer recommended to re-evaluate and re-deploy.

Acronyms and Abbreviations

Acronym	Definition
°C	Degrees Celsius
Al	Aluminum
AMOX	Ammonia Oxidation
APEEM	Advanced Power Electronics and Electric Machines Program
ARPA-E	Advanced Research Projects Agency-Energy
B	Boron
C	Carbon
CFD	Computational Fluid Dynamics
Co	Cobalt
CO	Carbon monoxide
CPES	Virginia Polytechnic Institute Center for Power Electronics Systems
CRADA	Cooperative Research and Development Agreement
Cu	Copper
CY	Calendar Year
DBA	Direct Bonded Aluminum
DBC	Direct Bonded Copper
DIC	Digital Image Correlation
DOE	U.S. Department of Energy
DPF	Diesel Particulate Filter
EGR	Exhaust Gas Recirculation
EV	Electric Vehicle
FEA	Finite Element Analysis
FFRDC	Federally Funded Research and Development Center
FSP	Friction Stir Processing
FSW	Friction Stir Welding
FY	Fiscal Year
GM	General Motors Corporation
GTRI	Georgia Tech Research Institute
HAADF	High-Angle Annular Dark-Field
HCCI	Homogeneous Charge Compression Ignition
HD	Heavy-Duty
HEV	Hybrid Electric Vehicle
Hf	Hafnium
HTML	High Temperature Materials Laboratory
ICE	Internal Combustion Engine
ICME	Integrated Computational Materials Engineering
IEA	International Energy Agency
IP	Intellectual Property
KSI	Kips per Square Inch

Acronym	Definition
MgO	Magnesium oxide or Magnesia
MPa	Megapascal
NH_3	Ammonia
Ni	Nickel
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NTRC	National Transportation Research Center
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
Pd	Palladium
PI	Principal Investigator
PM	Permanent Magnet
PNNL	Pacific Northwest National Laboratory
Pt	Platinum
PZT	Lead Zirconate Titanate
R&D	Research and Development
SCR	Selective Catalytic Reduction
Si_3N_4	Silicon nitride
TE	Thermoelectric
TED	Thermoelectric Devices
TEG	Thermoelectric Generator
TEM	Transmission Electron Microscopy
TEMats	Thermoelectric Materials
U.S. DRIVE	U.S. Driving Research and Innovation for Vehicle Efficiency and Energy sustainability
VTO	Vehicle Technologies Office
W/mK	Watts per Millikelvin
WBG	Wide Bandgap
WFO	Work for Others
WHR	Waste Heat Recovery
XRD	X-ray Diffraction
Zr	Zirconium
ZrO_2	Zirconium dioxide
ZT	Thermoelectric Figure of Merit