6. Materials Technologies

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

The Materials Technology (MAT) subprogram supports early-stage R&D of technologies for vehicle lightweighting and improved propulsion (powertrain) efficiency applicable to light- and heavy-duty vehicles. The MAT research portfolio supports the VTO goals of affordable transportation and energy security. Reducing the weight of a conventional passenger car by 10% results in a 6%–8% improvement in fuel economy, and similar benefits are achieved for battery electric and heavy-duty vehicles. Research focuses on activities that have a high degree of scientific or technical uncertainty or that are too far from market realization to merit sufficient industry emphasis and resources. The MAT subprogram accomplishes its technical objectives through research programs with academia, National Laboratories, and industry.

Propulsion Materials Technology supports research at National Laboratories to develop higher performance materials that can withstand increasingly extreme environments and address the future properties of a variety of relevant, high-efficiency powertrain types, sizes, fueling concepts, and combustion modes. The activity continues to apply advanced characterization and multi-scale computational materials methods, including high performance computing (HPC), to accelerate discovery and early-stage development of cutting-edge structural and high temperature materials for more efficient powertrains.

Lightweight Materials Technology supports National Laboratory research in advanced high-strength steels, aluminum (Al) alloys, magnesium (Mg) alloys, carbon fiber composites, and multi-material systems with potential performance and manufacturability characteristics that greatly exceed today's technologies. This includes projects addressing materials and manufacturing challenges spanning from atomic structure to assembly, with an emphasis on establishing and validating predictive modeling tools for materials applicable to light- and heavy-duty vehicles.

Project Feedback

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

Table 6-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat057	Applied Computational Methods for New Propulsion Materials	Charles Finney (ORNL)	6-7	3.17	3.17	3.17	3.00	**3.15**
mat069	Lightweight High-Temperature Alloys Based on the Aluminum-Iron-Silicon System	Michelle Manuel (University of Florida)	6-10	3.50	3.00	3.00	3.50	**3.19**
mat118	Functionally Designed Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composites Door Assembly	Srikanth Pilla (Clemson University)	6-12	3.50	3.20	3.50	3.00	**3.29**
mat119	Ultra-Light Hybrid Composite Door Design, Manufacturing, and Demonstration	Nate Gravelle (TPI)	6-17	3.30	3.20	3.30	3.10	**3.23**
mat122	Close-Proximity Electromagnetic Carbonization (CPEC)	Felix Paulauskas (ORNL)	6-23	3.50	3.10	2.80	3.10	**3.16**
mat124	Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles	Xiadong Li (University of Virginia)	6-28	3.38	3.38	3.25	3.38	**3.36**
mat125	Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber	Jeramie Adams (Western Research Institute)	6-33	3.30	3.40	3.60	3.30	**3.39**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat127	USAMP Low-Cost Magnesium Sheet Component Development and Demonstration Project	Randy Gerken (Fiat Chrysler Automotive)	6-39	3.38	3.25	3.63	3.25	**3.33**
mat131	Corrosion Control in Carbon-Fiber Reinforced Polymer Composite-Aluminum Closure Panel Hem Joints	Scott Benton (PPG)	6-42	3.00	3.00	3.50	3.17	**3.08**
mat132	High-Strength Steel-Aluminum Components by Vaporizing Foil Actuator Welding	Glenn Daehn (Ohio State University)	6-45	3.50	3.67	3.67	3.33	**3.58**
mat133	Corrosion Protection and Dissimilar Material Joining for Next-Generation Lightweight Vehicles	DJ Spinella (Arconic)	6-48	3.40	3.40	3.30	3.20	**3.36**
mat136	High-Performance Computing and High-Throughput Characterizations towards Interfaces-by-Design for Dissimilar Materials Joining	Xin Sun (ORNL)	6-53	3.25	3.75	3.00	2.75	**3.41**
mat137	Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel	Zhili Feng (ORNL)	6-56	2.67	3.00	2.50	3.00	**2.85**
mat138	Solid-State Joining of Magnesium Sheet to High-Strength Steel	Piyush Upadhyay (PNNL)	6-59	3.25	3.25	3.13	3.25	**3.23**
mat139	Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium	Scott Whalen (PNNL)	6-63	3.33	3.17	3.17	3.33	**3.23**
mat142	Metal-Matrix Composite Brakes Using Titanium Diboride	Glenn Grant (PNNL)	6-66	3.33	3.17	3.50	3.33	**3.27**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat143	Mitigating Corrosion in Magnesium Sheet in Conjunction with a Sheet-Joining Method that Satisfies Structural Requirements within Subassemblies	Aashish Rohatgi (PNNL)	6-69	2.88	2.88	3.00	2.63	**2.86**
mat144	Reducing Mass of Steel Auto Bodies Using Thin, Advanced High-Strength Steel with Carbon-Fiber Reinforced Epoxy Coating	Gabriel Ilevbare, Dave Warren; (ORNL)	6-73	3.17	3.33	3.00	2.83	**3.19**
mat146	Ultra-Lightweight, Ductile Carbon Fiber Reinforced Composites	Vlastimil Kunc (ORNL)	6-77	3.13	3.00	3.00	2.75	**3.00**
mat147	Continuous Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression-Forming Process	Dave Warren (ORNL)	6-81	2.50	2.38	2.75	2.50	**2.47**
mat149	Non-Rare Earth Magnesium Bumper Beams	Scott Whalen (PNNL)	6-87	3.13	3.25	3.25	3.38	**3.23**
mat150	Low-Cost Corrosion Protection for Magnesium	Aashish Rohatgi (PNNL)	6-90	2.50	2.75	2.75	2.63	**2.67**
mat151	Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints	Adam Powell (Worcester Polytechnic Institute)	6-94	3.00	3.17	3.50	3.17	**3.17**
mat152	A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives	Roozbeh Dargazany (Michigan State University)	6-97	2.60	2.80	2.90	2.90	**2.78**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat153	Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints	S. Jack Hu (University of Michigan)	6-102	3.50	3.50	3.67	3.50	**3.52**
mat156	Improving Tool Durability and Process Robustness in Assembly of Aluminum and Steel Sub-Components using Friction-Assisted Scribe Technology (FAST)	Piyush Upadhyay (PNNL)	6-105	3.20	3.40	3.20	3.00	**3.28**
mat157	Graphene-Based Solid Lubricant for Automotive Applications	Anirudha Sumant (ANL)	6-109	3.00	2.50	3.50	3.00	**2.81**
mat159	Powertrain Core Program: High-Temperature Lightweight Alloys–Aluminum-/Titanium-Based Alloys	Allen Haynes (ORNL)	6-111	3.25	3.25	3.50	3.25	**3.28**
mat160	Powertrain Core Program: Higher Temperature (>550°C) Alloys–Nickel-/Iron-Based Alloys	G. Muralidharan (ORNL)	6-113	3.50	3.50	3.00	4.00	**3.50**
mat162	Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys	Dongwon Shin (ORNL)	6-115	3.00	2.75	3.00	2.75	**2.84**
mat163	Multi-Scale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components	Mei Li (Ford)	6-117	3.50	3.33	3.17	3.33	**3.35**
mat164	Multi-Scale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials	Michael Tonks (University of Florida)	6-120	3.33	3.67	3.50	3.67	**3.56**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat165	Direct-Extruded High-Conductivity Copper for Electric Machines	Glenn Grant (PNNL)	6-123	3.50	3.67	3.67	3.33	**3.58**
Overall Average				**3.20**	**3.19**	**3.22**	**3.14**	**3.19**

Presentation Number: mat057
Presentation Title: Applied Computational Methods for New Propulsion Materials
Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

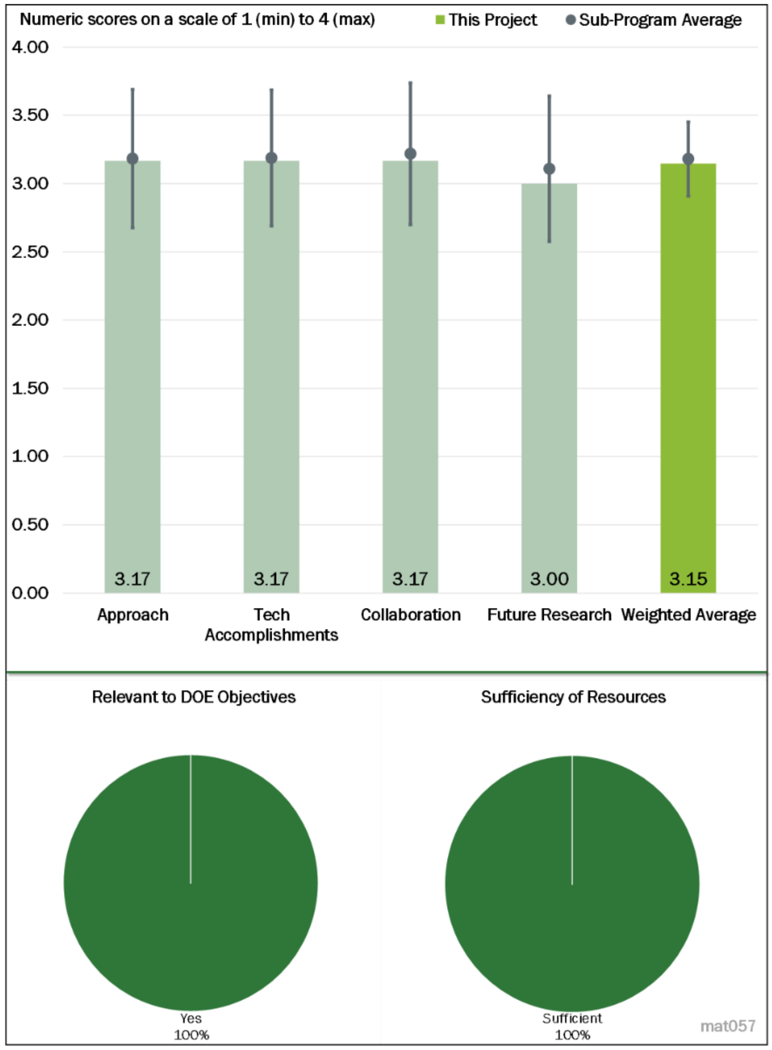

Figure 6-1 – Presentation Number: mat057 Presentation Title: Applied Computational Methods for New Propulsion Materials
Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

Presenter

Charles Finney, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the team's approach of integrating modeling with experimental explorations is appropriate and should yield good results. The team is focused on the right boundary conditions for future engines in its examination of SuperTruck I and II peak cylinder pressures—challenges with materials are significant with degradation at the temperatures likely for these future engines. The team is asking the right questions and focusing on an application (heavy-duty [HD] truck engine) with future potential. The team has demonstrated how the project has evolved over its lifecycle to focus on the proper research questions and build a knowledge base.

Reviewer 2:

The reviewer stated that the computational fluid dynamics (CFD) modeling and finite element modeling (FEM) activity of this project seek to determine/predict the effects of in-cylinder temperature and pressure effects on component materials under conditions of elevated pressure and heat flux to help accelerate the development of novel material formulations. There is good coupling with HD engine efficiency targets that require higher temperature materials to reach the efficiency levels needed going forward. Understanding where high temperature events are impacting the cylinder components and how the material reacts is very important to the survivability of both HD and light-duty (LD) highly efficient engines that work at higher temperature and pressure regimes. However, the focus is still HD. Because this is the last year of the project, there is little time to extend methodology to LD engines, even though LD will represent increased temperature challenges.

Reviewer 3:

This reviewer said the approach of coupling high-fidelity multiphysics simulations with low-fidelity simulations, and including new material data for new materials is a good approach to overcome the barriers outlined. The team clearly demonstrated this approach for one specific material: Compacted Graphite Iron. Tt would have been helpful for them to develop a general approach that could be used for other materials and applications, and then apply that approach to the specific material.

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

Reviewer 1:

This reviewer stated that the project team is making good progress and seems to be on schedule to finish by the end of the fiscal year (FY).

Reviewer 2:

The reviewer noted that the team is using an original equipment manufacturer (OEM)-relevant material and engine design for its effort. It is interesting that peak cylinder pressure is less important than temperature for head stresses as there is an order of magnitude larger stresses from temperature. Skillful use has been made of FEA modeling to isolate the stress effects in the most relevant portions of the cylinder head. The work certainly demonstrates the challenges faced by materials science in developing engine materials to meet the needs of future high-efficiency truck engines.

Reviewer 3:

The reviewer indicated that the base level work appears well grounded and focused. The use of both the CFD and FEM computational elements, to better assess and predict "hot spots" and fatigue risk in cylinder component material is worth supporting from a manufacturing and engineering standpoint. The predicted results appear to be fundamentally sound and consistent from experimental results. However, progress appears slower than expected in terms of providing additional insight into stress and fatigue mechanisms. Several of the combustion and materials findings are rather basic for a five-year project. Extending this work to LD earlier would have been a good comparison that would yield useful model information.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said they have a multidisciplinary team that has been working well together and the team has accomplished great things.

Reviewer 2:

This reviewer noted that collaboration and coordination with HD engine manufacturers is expected and is employed for this work. However, incorporating LD engine manufacturers such as OEMs would benefit the usefulness of this approach and gather additional support for this work.

Reviewer 3:

The reviewer remarked that the details of the collaboration with external partners are still vague (likely due to proprietary industry concerns) but the results of the industry collaboration are yielding the right results. The remainder of the project appears to be solely conducted by Oak Ridge National Laboratory (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:

This reviewer said it will be interesting to see what the team will find when moving from HD to LD as there are different considerations (performance, durability, operating conditions). The transfer of this modeling and experimental methodology to LD applications is certainly a logical next step for the team.

Reviewer 2:
This reviewer stated that because this is the last year of the project, the remaining time should be spent on extending the work to LD for comparison.

Reviewer 3:
The reviewer reported that the project is ending in September and therefore there was no future work presented. The team did give ideas of where they hope to go with the work in the future using other funding.

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

Reviewer 1:
This reviewer said the project is directly addressing Vehicle Technologies Office's (VTO) barriers in the area of materials to facilitate increased engine efficiency and will facilitate high temperature/high peak cylinder pressure future engines.

Reviewer 2:
The reviewer stated that this approach could have a huge impact on the future development of engine materials and technology.

Reviewer 3:
This reviewer said improved component durability under more demanding temperature and pressure conditions that are present in advanced, highly efficient engines is of high importance to manufacturers that are required to meet longer lifetimes of vehicle subsystems.

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

Reviewer 1:
This reviewer said the project team has accomplished good things with their resources.

Reviewer 2:
The reviewer observed appropriate resources.

Reviewer 3:
The reviewer stated that resources appear to be sufficient for the team to complete the extensive body of work described in the presentation.

Presentation Number: mat069
Presentation Title: Lightweight High-Temperature Alloys Based on the Aluminum-Iron-Silicon System
Principal Investigator: Michelle Manuel (University of Florida)

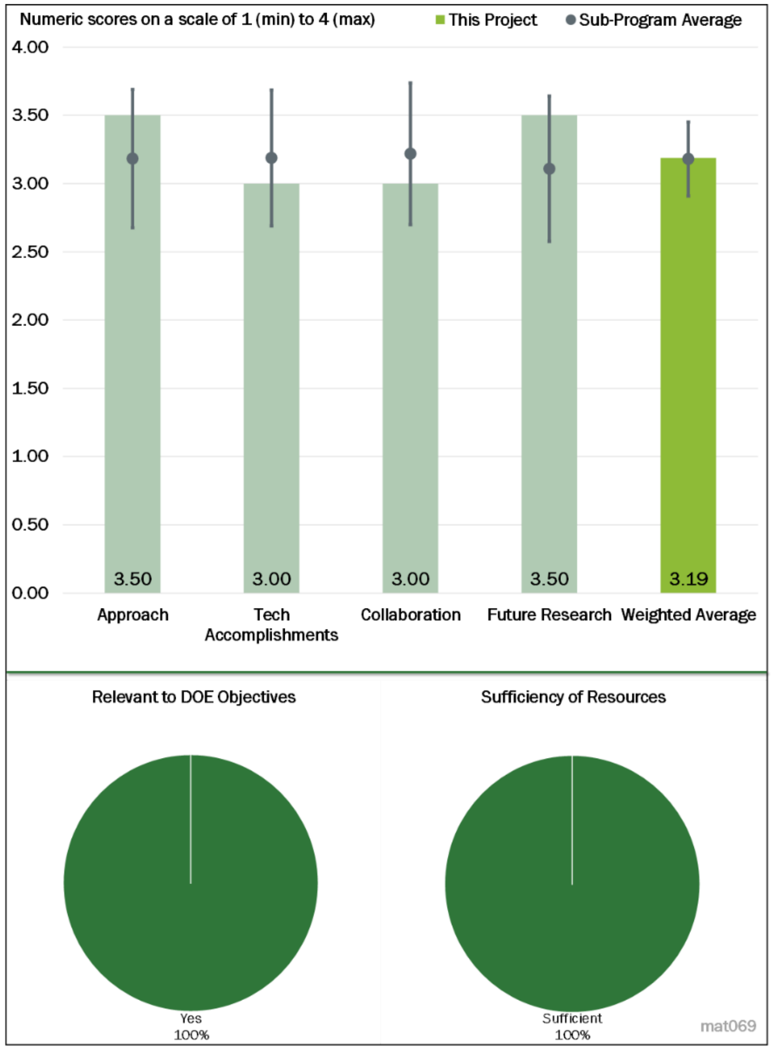

Figure 6-2 – Presentation Number: mat069 Presentation Title: Lightweight High-Temperature Alloys Based on the Aluminum-Iron-Silicon System Principal Investigator: Michelle Manuel (University of Florida)

Presenter

Michelle Manuel, University of Florida

Reviewer Sample Size

A total of one reviewer evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that this project used well-designed, targeted experiments to investigate the phase stability of a key system combined with a suite of integrated computational materials engineering (ICME) tools.

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

Reviewer 1:

The reviewer stated that the team investigated fundamental thermodynamic phase equilibria of the targeted system from both experimental and theoretical aspects. While the approach is sound, the accomplishment and progress to date seem lower than expected. Because most participants are from academics, more publication is highly anticipated. Also, the scope of the project is focused on the high-temperatures; there is not much convincing evidence that this class of materials can be used for high-temperature automotive applications.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer asserted that the results show good collaboration among the team members.

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

Reviewer 1:

The reviewer stated that the remaining challenges and proposed future work look good. However, the concern is whether the team can complete all the proposed work in time.

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

Reviewer 1:

The reviewer noted that the target materials aim to be used in high-temperature automotive applications, which is highly relevant to the DOE VTO mission/objectives.

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

Reviewer 1:

The reviewer observed sufficient resources to perform the proposed research tasks.

Presentation Number: mat118
Presentation Title: Functionally Designed Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composites Door Assembly
Principal Investigator: Srikanth Pilla (Clemson University)

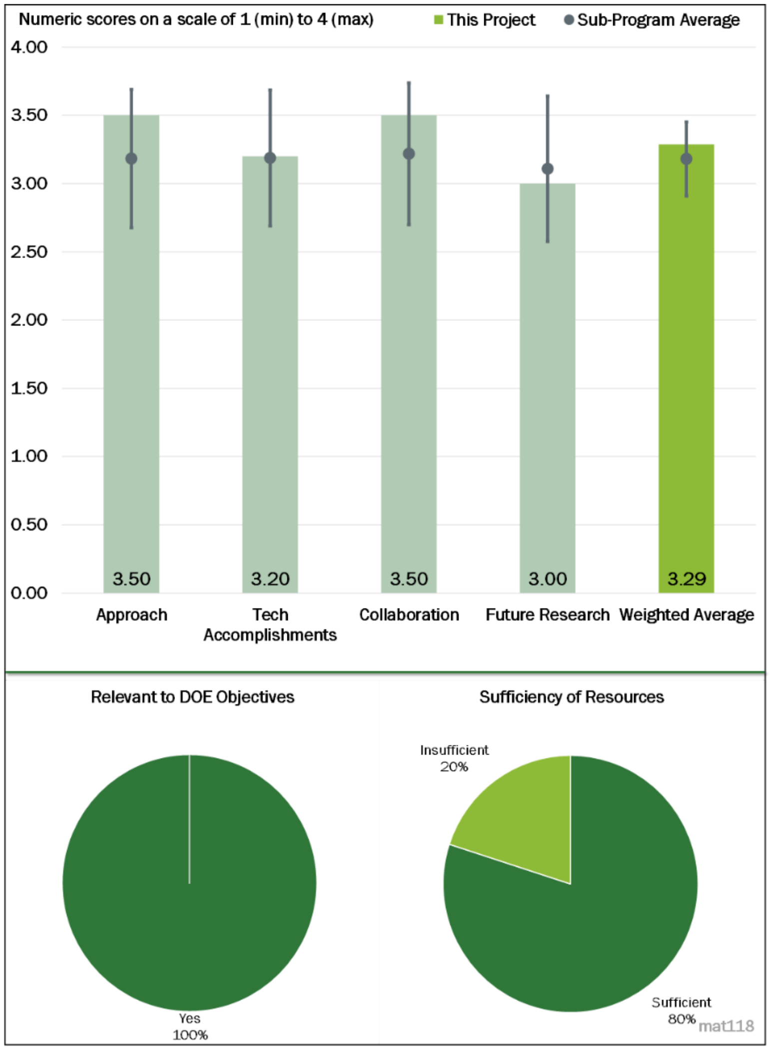

Figure 6-3 – Presentation Number: mat118 Presentation Title: Functionally Designed Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composites Door Assembly Principal Investigator: Srikanth Pilla (Clemson University)

Presenter

Srikanth Pilla, Clemson University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer stated that the team has done a very good (excellent) job in their approach to this work. From the scoping of the requirements in terms of projected costs, mass savings opportunities and integration, this is a challenging endeavor. The Clemson-led team working closely with an engaged OEM did a fine job of identifying where the efforts needed to be applied. The overarching goals of prescribed weight savings (42.5%) and incremental system cost (less than $5/lb. of weight saved) are very challenging given that so much system weight is embedded in non-structural but functional components (although kudos for obtaining support to lessen glass weight by Corning—this improves the technical approach too) that are not addressable in this scope. The principal investigator (PI) presented a clear understanding and created an approach to address the structural weight savings and overcome this natural handicap. Given the preliminary design was predicated on static load considerations, and the team needed to pivot based on shortcomings seen in dynamic (crash) performance, the response was rapid and adequate. The result of a multi-material solution to address weight savings and yield a design that (through analysis) meets safety and user requirements is commendable.

Reviewer 2:

The reviewer indicated the presentation was very well organized, was focused on the approach and how they met the requirements. The research was very well focused on achieving the mass and performance of the door. Simulation and experimental data were used very well together with iterations on the door system that was able to meet the crash requirements.

Reviewer 3:

This reviewer described the overall approach as strong. However, Slide 5 on Approach is not accurate. The reporting period is shown as Year 2 however the project is currently into Year 4 of operation. The chart of what is successfully completed, and what tasks are still in progress or delayed does not agree with other descriptions in the presentation. An item missing in approach is the assembly operations with attention to read through and tolerance of fit up relative to desired door to body gaps.

Reviewer 4:

The reviewer stated that the approach seems adequate to make progress and deal with emerging issues as the work proceeds. A few examples were given during the presentation of instances where shortfalls in initial performance or design were detected, and steps were taken within the approach to correct these shortfalls.

Reviewer 5:

This reviewer said the static and dynamic test scenarios provide a good idea of how the proposed design compares with the baseline. Honda is known for stringent testing of their components and systems, so the PI has made a credible case that their design would meet Honda's crashworthiness, structural, and functional expectations. The cost structure of the composite door appears to compare with the baseline (based on the Q&A) but the cost aspect needs to be firmed up. Because the design is fixed, it should not be difficult to estimate the cost for a 20,000 run production. The weight target has not been met, so this should be a priority in the next cycle, although the proposed schedule deals mainly with tooling and testing. The reviewer asked how the required weight reduction is going to be explored if the design is frozen.

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

Reviewer 1:

This reviewer stated that the technical accomplishments have been notable and follow the milestone described at the start of work. About 65% of the milestones have been met.

Reviewer 2:

This reviewer noted that the project at this point is quite mature having reached the fourth year of actual reporting (2016, 2017, 2018, and 2019). The successful effort to design a door meeting performance based upon the computer-aided engineering (CAE) modelling, data generation, and projected cost requirements for meeting incremental cost goals is also commendable. The pivot to a multi-material-based structural solution was (apparently) rapid and not unusual from a real-world perspective moving from preliminary to detailed design stages.

It does seem that the tooling fabrication and manufacturing element of this project is coming pretty late in the program timeline and compresses critical elements of hardware development, fabrication, assembly, and testing. Given the delays related to installation of facilities not yet in place at the onset of the effort, this is not necessarily unexpected. This reviewer is concerned, however, that lead times in tooling and some necessary learning curve elements in molding the inner and outer panels will challenge even this extended schedule. The work is worth doing, so no additional cost extensions or other means to accommodate an extended schedule should be tolerated.

Reviewer 3:

This reviewer noted that the project accomplished the weight and performance targets. There were some areas where there needed to be changes. This reviewer is not sure why the need to add aluminum (Al) at the bottom of the door versus making a change in the composite in that area of the door and compare the results. If a composite patch area could have been made it would have eliminated a stamped Al part with bonding to the door.

Reviewer 4:
The reviewer commented that progress and accomplishments are good for FY 2018. The concept of the door design has progressed. This reviewer had wanted to see a full Bill-of-Materials with weights and costs. This reviewer questioned the use of thinner material with selected ribbed reinforcements on the exterior panel. This often generates unacceptable witness marks or “read through” on the class-A surface. The design does not include any water barrier to keep the window motor, speaker, and other internal components dry during vehicle use. The exploded views should show the full door construction and all the components. The assembly and painting of the door has not been addressed in this project, which often influences the design, especially for composites. The claimed crash accomplishments are difficult to verify because there are as yet no physical tests to CAE comparisons shown in the review. The CAE guidance without any physical testing is suspect. A static stiffness test and a simple natural modes test to CAE would be valuable comparisons.

Reviewer 5:
This reviewer noted that, relative to other projects presented in the AMR meeting that deal with door lightweighting, this project has not made the same amount of progress. The progress was made on design—though as a first-time reviewer of this project it is unclear why so many iterations were necessary to arrive at the design presented (version 11). Even then, this design does not meet the weight target and the cost structure is preliminary as presented. The recyclability criterion was self-imposed, but this reviewer missed how the team made any progress on this point. In general terms, in roughly 3.5 years the team iterated toward an interesting design that promises to meet structural/functional criteria but which has an unclear cost structure. Also, the uncertainties/challenges of tooling and manufacturing are yet to be elucidated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer said the team had a great integrated team and it was clear that they worked well together with the success of meeting the performance goals of the project.

Reviewer 2:
The reviewer observed that the two universities, the OEM (Honda) and the material supplier appear to be cooperating well. It would help with clarity if the presentation included the regular meeting and interaction cadence. If the team is meeting once a month or once a quarter as a full team, let us reviewers know.

Reviewer 3:
This reviewer said the partnership is strong, though as presented it seems that Delaware's contribution was significantly less than the PI and the OEM.

Reviewer 4:
The reviewer observed that the team seems to function well, although it appears that Clemson University is doing the bulk of the work.

Reviewer 5:
This reviewer said that there seems to be strong support and coordination from all four key organizations and the supporting suppliers of software and materials. Clearly the OEM engagement is strong and supported many of the requisite design elements that are essential to commercialization of this technology. Similarly, the detail in the dynamic modelling required strong coordination with University of Delaware and the OEM for successfully constructing and running simulations.

The only possible criticism (and it is mild) would be earlier efforts in manufacturing modelling and/or CAE work to develop a shorter lead time with tool manufacturing. Indeed, it is better to delay cutting tools than starting early and wasting expensive tool fabrication time and cost, but serialization operations is clearly a schedule extender. However, the extended delay discussed to create the Clemson pilot fabrication facility does not fully explain the delay in the design effort or necessarily delays in efforts to go forward with tool fabrication. May itself be an issue with collaboration.

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

Reviewer 1:
This reviewer stated that the future work is consistent with meeting the remaining goals and milestones. Areas of improvement include: assessment of durability of the thermoplastic composite parts over time to determine whether the composites will degrade over time to render the doors unsafe during a crash; how the composite material ages and what the expected reduction in performance over time is; and how long these composite parts are expected to last under extremes (and ambient/mild) of temperature and weather conditions. This reviewer also indicated that crash tests are reported in materials deformation (intrusion) characteristics. There are no data on force absorption characteristics. Indicated whether more or less force is transferred to the occupants in the car compared with steel doors. These data are usually available from instrumented crash dummies. Please present it. Lastly, the reviewer observed there is still some weight to be removed from the door (1.04 kg), and commented that no task is identified in future work to do this.

Reviewer 2:
This reviewer said there is not much to remark on here, the proposed work ahead of this team has been cut out and is clear. Validate analysis and fabrication plans through subcomponent testing, build the tools, fabricate the parts, and assemble door systems. Proposed future work does not include (in scope) a full-scale door crash test or other efforts to confirm form fit and function with an automobile, although it is reflected at the start of the review as a milestone.

Reviewer 3:
This reviewer asked if there could be further improvement with the elimination of the Al part at the bottom of the door. The final push of the project has the right direction for the future research.

Reviewer 4:
The reviewer indicated that getting the design frozen and starting the tooling are the best next steps. The long lead tooling requires that the final door will be heavier than target. The testing plans on the top hat section should be better defined for clarity. This reviewer suggested doing natural frequency mode shape testing, static bending, and torsion testing along with the more glamorous crash and impact testing. Also, the full testing plan for component, door alone, and door-on-vehicle is not clear.

Reviewer 5:
This reviewer stated that key questions remain in relation to weight reduction (which may not be addressed judging from the work plan). The challenges of tooling and manufacturing will be elucidated in the upcoming cycle, but this presents uncertainty.

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

Reviewer 1:
This reviewer stated that fabrication of lightweight components for transportation systems (whether they be chassis for automobiles, trucks, buses or other ground modes) is critical to meet the future requirements for lower carbon emissions (whether in fuel economy standards or direct measurements of emissions per km). DOE has presented a remarkable challenge in choosing a door closure component that integrates so much functionality in a highly structural component with occupant safety standards necessary to sustain life. Successful accomplishment of the goals or even small gaps in the cost and weight performance goals will yield benefits far beyond door closure systems in automobiles. The knowledge and demonstration of feasibility will

transfer across the platform and transportation modes yielding economies that will improve lightweighting in all transportation fields. The project is a force multiplier that can be leveraged to support lightweighting and the overarching goal of improved fuel economy and lower carbon emissions. Indeed, the material choices made support sustainability in terms of material recycling as well.

Reviewer 2:
The reviewer remarked that the program is framed within the pertinent DOE VTO call.

Reviewer 3:
This reviewer said yes, the work supports the overall DOE objective of reducing auto glider weight.

Reviewer 4:
The reviewer indicated that this project does support overall DOE objectives; it meets the 42.5% weight reduction and $5/lb cost targets.

Reviewer 5:
This reviewer stated that lightweight doors will help reduce vehicle mass and improve fuel economy. This project will help address design, manufacturing, and testing issues for composite structures.

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

Reviewer 1:
This reviewer said the resources are appropriately allocated and each team member is performing within their budget with great results.

Reviewer 2:
The reviewer stated the team appears to have access to the experimental and computational resources needed to execute the project, and offered no concerns.

Reviewer 3:
The reviewer noted that the remaining budget seems adequate to complete the work to be done. However, it is hard to say, because there is no information about how much has been spent of the budget.

Reviewer 4:
The reviewer commented that insufficient resources remain, based upon available information in the presentation. Tooling and fabrication costs have not been identified, so assumptions are made. This may be the most significant challenge for the team. While original budgets established appear sufficient for the program, the late stage of progress in tool and component manufacturing, along with post fabrication fit up and testing make the funding resources a question mark. With four-fifths of the budget expended and the cost of fabrication remaining, it is not entirely clear where the budget stands, but from the perspective of the reviewer there should be some concern. It would be anticipated that tool cost, component cost, and door testing would consume a large component more than one-fifth of the budget. Some transparency here is needed.

Reviewer 5:
This reviewer said the overall budget should be more than sufficient for the project, including the prototype and testing.

Presentation Number: mat119
Presentation Title: Ultra-Light Hybrid Composite Door Design, Manufacturing, and Demonstration
Principal Investigator: Nate Gravelle (TPI Composites)

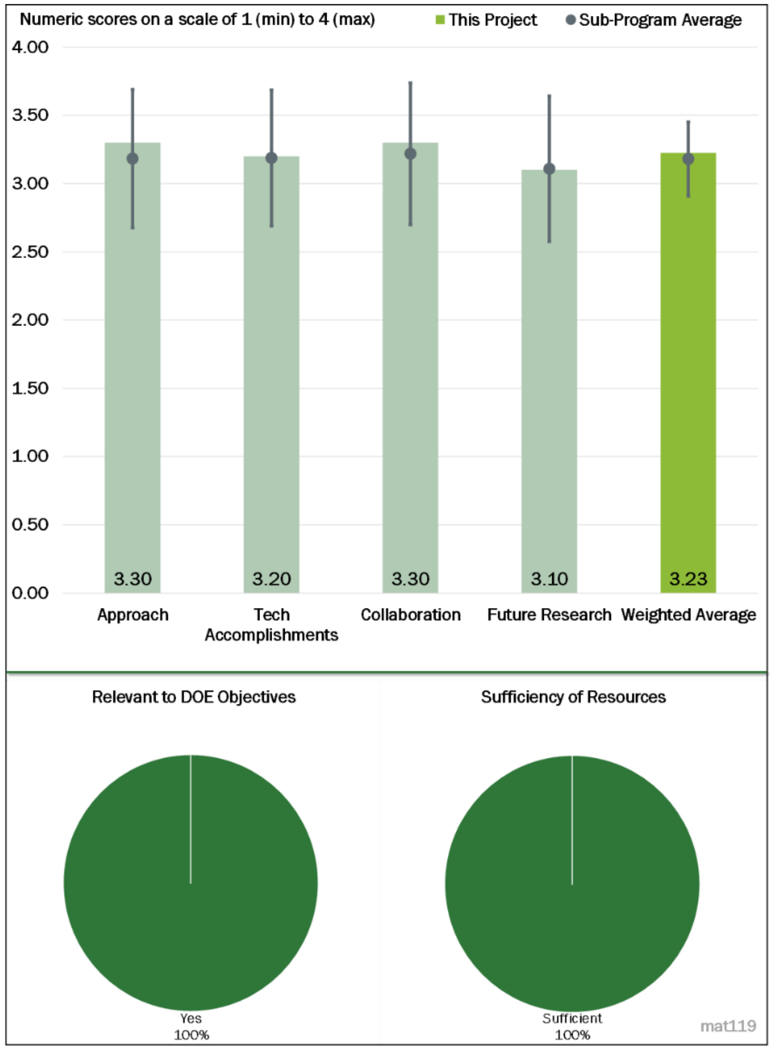

Figure 6-4 – Presentation Number: mat119 Presentation Title: Ultra-Light Hybrid Composite Door Design, Manufacturing, and Demonstration Principal Investigator: Nate Gravelle (TPI Composites)

Presenter
Nate Gravelle, TPI Composites

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer observed a very interesting project that appears to be one of three "sister" projects, each looking at the same end-use application of an automotive door, and each considering a different candidate material solution, be it Al, thermoplastic composite or, in this case, thermoset composite. In this case, significant work was done on developing the preform geometry and the resin lay down, both using existing simulation tools. In the experiment, the preform geometry proved problematic, for reasons including the stitch pattern, and alternative materials, stitch patterns and preform geometries are all being considered. The project is well-focused on the barriers of cost, cycle time and mass, though technical challenges do remain.

Reviewer 2:
The reviewer noted that this project started more than three years ago. The approach was not discussed in detail; but it looks like the team met the go/no-go decision point of three-minute cure time for high-pressure resin transfer molding (HP-RTM) of composite doors, and other criteria are being met.

Reviewer 3:
This reviewer noted that during the presentation it was not clear how or why the team's approach was reducing the weight. It was clear that the team was demonstrating a part molding process for the door inner, but it was not clear on how it was reducing weight. If there was more focus on the door design before the manufacturing and demonstration while the project was delayed, there may have been more opportunity for iterations for further weight reduction. It also sounded like there was a tight timeline for tooling build and the material supplies which impacted the front-end iterations, because tooling design needed to be locked in.

Reviewer 4:

The reviewer stated that the technical barriers identified were mainly in terms of cycle time; mass/weight; and cost metrics. By working towards HP-RTM, the team has been able to reduce the cycle time. The team indicates part to part cycle of 4.2-minute time, use of 2-minute fast cure resin, and innovations in injection technologies. This brings the project team's cycle time to an attractive metric. If the project team did this with conventional processes, it has identified that the cycle time may be up to 1 hour per part.

Regarding mass, the team has indicated a weight savings of 38% over the incumbent solution. The reviewer reported that the team has achieved this through materials by design—and use of carbon fiber (CF) where needed in the design. Their weight reduction target is 42.5% and on Slide 15, the project team indicates it will be more aggressive. The reviewer further noted that the team's current materials and methods utilize steel as the main structural component, which is mass heavy and less fuel efficient.

Regarding cost—one of the major light-weighting materials at disposal—this reviewer reported that the project team's incumbent CF metric costs upwards of $10-15/lb. The team's cost analysis considers two types of fibers: a $7.75/lb version and a $4.75/lb version. The basis or which specific fiber was used to benchmark the $7.75/lb was not fully clear to this reviewer, who also highlighted that the Oak Ridge fiber is still not a commercially available fiber. Hence, the latter is mainly a paper exercise to simulate a "what if" scenario.

Reviewer 5:

The reviewer noted that the barriers were clearly identified: cycle time, weight, and cost. The cycle time was addressed with the injection technology, the mass appeared on target (as demonstrated with prototypes). The costs were still being evaluated; however, the Oak Ridge low-cost carbon fiber (LCCF) was identified as needed to meet targets. Joining and assembly assumptions were not presented and cost calculations presented do not appear to take into consideration joining and assembly costs. This information is needed and would be more useful to fully assess the value and relevance of the project for automotive manufacturing. Also, the reviewer asked what the calculation assumptions are to deliver 75,000 units per year at a cycle of 4.2 minutes per mold (hours/week, line uptime efficiency, downtime, weeks/year, etc.). It would be preferred if the project's automotive OEM would have been identified to provide general context of product type, production volume, and in-service requirements (i.e., sport utility vehicle versus truck versus passenger car versus sports car, as well as local market versus global market).

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

Reviewer 1:

This reviewer said that a six-month delay in manufacturing was accounted for, and the project is on track for the milestone target.

Reviewer 2:

The reviewer stated that the technical barriers identified were mainly in terms of cycle time; mass/weight; and cost metrics. The cycle time metrics/indicator is well along the way and it appears that will be met or exceeded. Here the prototype scenario has to be taken to a mass production exercise, which the team kind of does in showing 4.2 minutes between parts. The team's update of the preform to overlap preforms seems to have been effective in minimizing fiber wash during HP-RTM. For further validation of the cycle time, perhaps the system level manufacturing, material preparation, and consistent control of process parameters may be influencing factors for this metric.

Regarding mass, the team has indicated a weight savings of 38% over the incumbent solution, and the weight reduction target is 42.5%. The reviewer was not fully clear what steps would be taken to further reduce the weight, without compromising performance. The team has attempted different fabric architectures to preserve fiber morphology during HP-RTM for example, but the reviewer asked how each iteration influences the projected weight. This was not very clear.

The full component cost solutions must provide more detail on the elements of the cost. The cost analysis considers two types of fibers—a $7.75/lb. version and a $4.75/lb. version. The basis or which specific fiber was used to benchmark the $7.75/lb was not fully clear to this reviewer, who also highlighted that the Oak Ridge fiber is still not a commercially available fiber. Hence, the latter is mainly a paper exercise to simulate a “what if” scenario. So, among cycle time, weight, and cost, the team should be commended on the cycle time, while the weight and cost are iteratively reduced, and the team may get there—the reviewer is just not sure it is demonstrated yet.

Reviewer 3:

The reviewer noted that TPI has already demonstrated the 3-minute cure time go/no-go decision point in 2017. Currently, the team is conducting a 4.2-minute part molding cycle with 2-minute resin cure time. The finish issue exists, but overall a great progress. The cost reduction comparison is somewhat questionable. LCCF cost from ORNL (less than $5/lb.) is the manufacturing cost and not necessarily the price of the material.

Reviewer 4:

This reviewer observed that the project is still short of the weight savings goal and it was not clear how the team is going to meet that goal. It was discussed that the team would meet the cost target goal by using the LCCF from ORNL. However, there may be some processing issues that are unknown using that fiber.

Reviewer 5:

The reviewer noted that while the project was delayed for some months owing to experimental setbacks, the team is anticipating wrapping up by end of 2019. This appears to be somewhat aggressive considering the number and significance of the experimental challenges that remain. What appears complete is the modeling and design piece—the team indicated that the design is locked and has been for some time. However, issues with the preform geometry and issues arising in the preform forming step, namely the appearance of a preform delamination and sliding of the preforms relative to one another seem significant. Recently, different stitch options and weave patterns have been introduced with the hope to reduce or eliminate some of these experimental challenges. However, it is likely that significant experimental effort will be needed to explore these options and there is no strong evidence-basis for confidence that these efforts will result in the hoped-for improvements. Finally, it was brought up that to meet the cost targets, the LCCF from Oak Ridge should be considered, should it become commercially viable. Aside from the uncertainty with this latter claim, it is likely that the LCCF would require an additional significant experimental program to understand the implications and possibilities of processing with the LCCF.

In summary, a number of major technical barriers seem to remain or even be amplified this late in the program. If the objective of the project is a feasibility study, then this is successful. If the objective is fabrication of a successful door, then significant issues remain.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said there is excellent partnership in the overall team comprising TPI Composites (the Project Lead); University of Delaware; a U.S. automotive OEM; Hexion; Krauss Maffei; Chomarat; and Atkins & Pearce (A&P). The work convinces the reviewer that the fiber/fabric suppliers Chomarat and A&P, resin supplier Hexion, HP-RTM Kraus Maffei, and the OEM guidance have been key in the development. Because the modeling, simulation and characterization results were less included (perhaps because of space and time), the contribution of University of Delaware was less clear in the information presented. Again, this may be due to priority of information in a short time available to present at the review. The overall teaming is excellent and roles of the partners are needed.

Reviewer 2:

The reviewer noted the presenter addressed the comments from the previous review. Moreover, the team is bringing in new partners to address technical barriers as they come up. For example, Chomarat and A&P

Technology have both been approached to provide non-traditional fabrics/weaves to the project in an attempt to address some of the processing challenges induced by the previous choice of fabrics.

Reviewer 3:

While the OEM was not disclosed, the reviewer commented that the supply base and university partners were identified, along with their contributions and role in the achieving deliverables.

Reviewer 4:

This reviewer stated the project demonstrates excellent teamwork. It has several segments and without a good teamwork it is not possible to accomplish what this team has done so far.

Reviewer 5:

It was clear to this reviewer how the PI worked with some of the team members, but there was good work that was not discussed with some of the other team members.

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

Reviewer 1:

This reviewer said there is a clear direction forward. The team appears committed and understands the next steps in assembling the door. What is unclear is exactly how and when these alternative technologies, such as the various weave or stitching patterns, or the LCCF may be incorporated into the design. It is unclear if the plan is to go forward with the current, as-built door and subject the current door/design to the testing program, or if the plan is to improve the door/design and then execute testing.

Reviewer 2:

This reviewer noted that despite a six-month delay, the project is on track for the door build.

Reviewer 3:

The reviewer said the future work plan needs LCCF from ORNL for cost reduction.

Reviewer 4:

It was clear to this reviewer what the project team was going to do in the future, but not how that proposed research was derived. There was no discussion of the door design team inputs on the direction of the future work. Alternatively, the reviewer asked whether it was totally based on observations that needed to be corrected.

Reviewer 5:

This reviewer noted that proposed future research was somewhat a laundry list of things the project team would do. There was not much distilled information to ascertain challenges within the proposed research. For example, regarding plans for creating parts with LCCF from ORNL for cost reduction, the reviewer asked what the form of the fiber will be; what generation/make-up of the precursor would be used; what would be its modulus and strength target; how much material would be sourced; and if there has been specific discussions of sourcing this and converting it to an intermediate such as non-crimp fabrics friendly for HP-RTM. Such questions remain nebulous.

Regarding future work on preforming for an HP-RTM part to minimize fiber waste and reduce cost, the reviewer asked how and what methodology will be used to minimize fiber waste, and about the costs incurred in preparing the preform. The plan is somewhat vague.

The team identified a whole list of components of door internals as potential for mass reduction, including things such as window glass; window guidance system; mirror; check link; hinges; molding system, etc. The reviewer asked how the team proposes to reduce the weight of window glass when the compositions of these are very standard and fixed, and if the work scope will allow them to steer their work to components that cannot/will not use CF and related processes. The same comment applies to most of the parts/components the team has identified here. These seemed a little less thought through from this reviewer's perspective.

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

Reviewer 1:
The reviewer asserted that this project is well-focused on the three main, DOE-specified objectives of cost, weight, and cycle-time.

Reviewer 2:
This reviewer stated yes, this project delivers on DOE objectives to develop viable manufacturing flow paths for CF composites for automotive applications.

Reviewer 3:
The reviewer emphatically stated yes, the project does support overall DOE objectives. Vehicle weight reduction is an objective of DOE for meeting the energy efficiency needs. This reviewer added that replacement of metals by carbon fiber reinforced polymer (CFRP) is a way, and this project is making good progress on that goal.

Reviewer 4:
The reviewer agreed that the overall project is consistent with the DOE objectives of mass reduction, cost reduction (possibly), and improving manufacturing efficiency. Once the development gets past the R&D challenges, the materials by design and manufacturing has merit to transition to a mass producible component. Although the OEM was not specifically identified, that aspect of the relation will be key to see if the project can migrate into commercialization.

Reviewer 5:
The reviewer indicated that this project is working toward the DOE objectives and that is the team's focus, but they are currently short of meeting or exceeding the 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 stated that the overall budget appears consistent with the program objective.

Reviewer 2:
This reviewer remarked that the resources seem sufficient for this project.

Reviewer 3:
The reviewer commented that the resources are sufficient, and at this point it is irrelevant because the project is ending in six months.

Reviewer 4:
This reviewer stated that the team is fully resourced, and they have a great team that would be capable of meeting the DOE goals.

Reviewer 5:

The reviewer remarked that the resources shown towards the project were much needed and available. The team's uses of the large press, tooling, and HP-RTM, as well as relationships with the performers are key to this project and are well leveraged.

Presentation Number: mat122
Presentation Title: Close-Proximity Electromagnetic Carbonization (CPEC)
Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Presenter
Felix Paulauskas, Oak Ridge National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

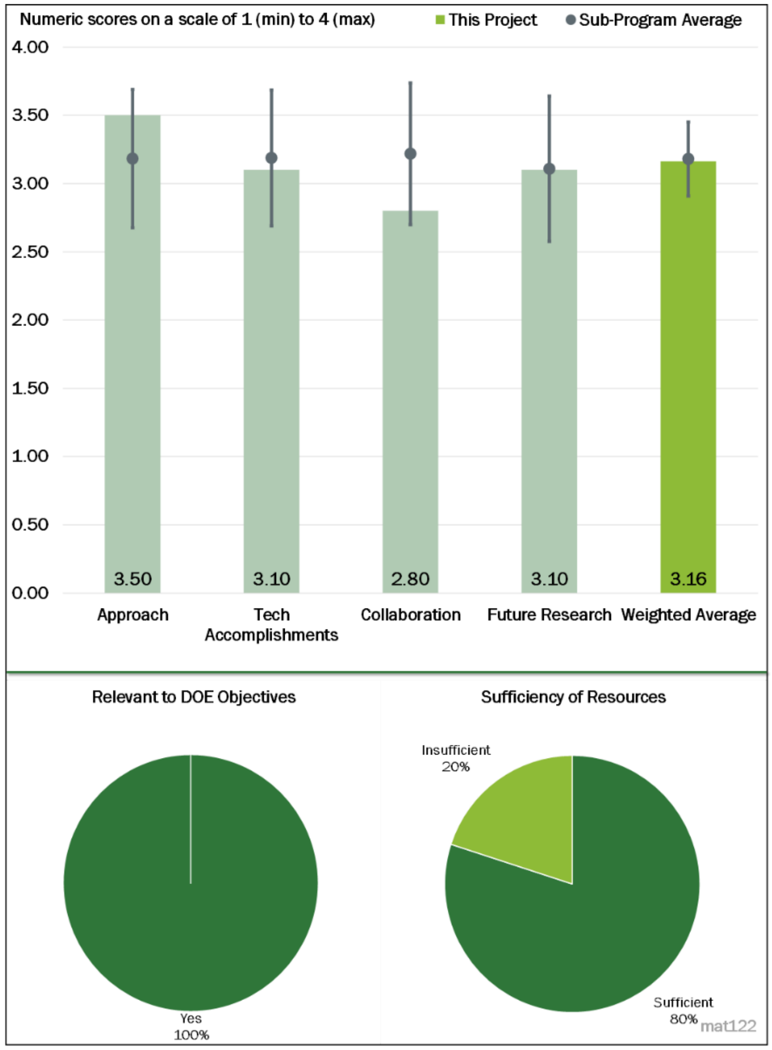

Figure 6-5 – Presentation Number: mat122 Presentation Title: Close-Proximity Electromagnetic Carbonization (CPEC) Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer described the approach as outstanding. The project to scale up the technology is difficult, but the needs are huge. This is an excellent example of long-term commitment to overcoming barriers to make advanced technology useful for industry.

Reviewer 2:
The reviewer stated that this is an excellent project. The approach is creative and has the potential to reduce cost through electromagnetic carbonization.

Reviewer 3:
The reviewer observed a good approach of reducing the energy requirements through dielectric heating.

Reviewer 4:
This reviewer stated that the project is based on the premise that conventional furnaces consume significant energy heating large volumes of inert gas surrounding the fiber. If thermal energy could be directly coupled from an energy source to the fiber, significant energy savings could be realized. The reviewer commented that this project addresses a significant technical challenge of Close Proximity Electromagnetic Carbonization (CPEC), and the team is investigating a low temperature carbonization (LTC) process. This reviewer explained that the team relies on dielectric heating (no convection), and has shown that the process is faster and more efficient than conventional. The work is accomplished at atmospheric pressure. The project strives to reduce unit energy consumption of the LTC stage (kWh/kg) by about 50%, which translates to 5% of the cost reduction on the CF's overall manufacturing process. The reviewer reported that the team's goal is to produce equal or better quality CF, and the eventual goal is to scale the technology to a nameplate capacity of 1 annual metric ton.

Reviewer 5:

This reviewer believed the concept and approach used by the PI in the low-temperature carbonization of polyacrylonitrile (PAN) fiber for CF manufacturing is both thoughtful and effective for reducing energy consumption and improving throughput. The steps to demonstrate feasibility and work through scaling of the process appear to have been challenging with the final scale up of the so-called CPEC-4 equipment, however, it is work that is essential toward demonstrating the potential of reducing cost and expanding capacity. More detail related to the approach to reduce process variance in the development of a suitable controller for the CPEC-4 equipment would have been appreciated by this reviewer, who felt as if the PI was hand-waving a bit and expressing a “trust me” attitude. While respected and revered some insight into the feedback mechanisms in the control system or a basic control loop design would have instilled more confidence that variability in the processed materials will be reduced.

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

Reviewer 1:

This reviewer stated that the project has accomplished much in terms of milestones. The project is on track and in good shape. The electromagnetic carbonization facility has been on schedule through the collaboration with 4X Technologies, LLC.

Reviewer 2:

This reviewer noted that the project has evolved in stages since 2016 and is addressing a significant technical challenge ranging from material development, equipment optimization, successive iterations, property optimization to meet DOE targets, and pathway to commercialization. The overall technical accomplishments and technical progress is excellent. A lot of the June 2019 review focused on the development, installation, iterations, challenges, and overcoming of them with respect to the CPEC asset. The reviewer remarked the team has successfully completed assembly of CPEC 4 and demonstrated stable/proper operation of all subcomponents for 20 minutes. The team has also successfully carbonized 4x24k tows with final mechanical properties of greater or equal to 250 ksi tensile strength and 25 Msi Modulus in under 60 seconds. The team is making progress to demonstrate at least 5% cost savings of the overall CF manufacturing process using CPEC technology versus conventional carbonization.

Reviewer 3:

This reviewer noted that the work completed on the CPEC-3 equipment was discussed and showed promising results related to meeting targets for CF strength and modulus even with lack of closed loop control. Significant variance in the data show only 20% or so of material meeting minimum targets. The cause of this variance is explained as a result of manual (open loop) control in a very dynamic environment. The reviewer remarked work to build a LabVIEW based controller was described and is an important component of CPEC-4. The PI described progress in the construction of the CPEC-4 equipment, but due to circumstances, significant delays in the delivery and assembly were discussed. The reviewer remarked it was good to see that as of May 2019 the CPEC-4 is operational but still a work in progress (8-month delay of the ordered equipment).

Reviewer 4:

The reviewer noted that the technical progress is behind schedule due to supplier delivery and equipment difficulties. While this is disappointing, it is not uncommon. The commissioning of the vessel appears to meet expectations. The efforts to develop and tune the control system appear to be adequate to meet the project goals.

Reviewer 5:

This reviewer said it seems the progress could not be made as expected due to a delay in delivery of the generator. This is very much understandable. This reviewer wondered whether some correctional measurements could have been taken with more project management. The reviewer could not find any computer modeling results to design the processing conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer stated that there has been good collaboration with the industrial partner specialized in plasma science.

Reviewer 2:

This reviewer noted that the PI has been collaborating with 4X Technologies. The team has made progress in a timely fashion to address the critical needs for LCCF through low-temperature carbonization.

Reviewer 3:

The reviewer identified the key collaborator on this project as 4X Technologies and that relationship seems to be working well for the researchers. The 4X collaboration is in terms of joint development, equipment construction, and experimental work. 4X's expertise in plasma science and engineering, fiber treatment/conversion, and environmental applications is being integrated heavily in this work. There were no other specific collaborators on this project.

Reviewer 4:

This reviewer said it is very difficult to properly assess and “grade” a program like this as an external reviewer that does not live the day to day frustration regarding progress of a complex and newly developed technology. Nonetheless, the late delivery of a piece of equipment critical to the timeline of a highly funded program must suggest challenges in the coordination and collaboration of the primary participants. The PI provided reviewers with a timeline of events to outline circumstances; it is arguable that closer coordination between the stakeholders may have mitigated the delays and accelerated progress. This reviewer does not care to be critical as the reviewer cannot offer constructive advice on what remediations would have been effective at shortening the delay. Ultimately, if no additional cost extension granted to the PI results in successful demonstration of the technology and the effectiveness of the closed loop control is validated, the project collaboration will be seen as a success.

Reviewer 5:

The reviewer stated that there is no discussion in this presentation on the roles and responsibilities, or the interactions between ORNL and 4XTechnologies. Considering the project delays, this reviewer had expected more discussion on the project management of the partners to get to the goal.

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:

This reviewer said the future work is well planned. The installation of electromagnetic carbonization facility is on track and in good shape. The pilot scale run will help the cost estimation.

Reviewer 2:

The reviewer stated that the future work is very challenging, but a good plan is in place.

Reviewer 3:

The reviewer reported that this project is scheduled to come to conclusion at the end of FY 2019. By this time, the team will conduct studies to evaluate the following: normal operation of CPEC-4 with 4 tows and 24k with 60s achieving 250 ksi /25 Msi; an economical evaluation of this technology; and propose research for a comprehensive solution for full carbonization process based on CPEC technology. In this reviewer's view, all of these are relevant and worthwhile directions for future research.

Reviewer 4:

The reviewer noted that the PI expressed the urgent effort to fulfill milestones MS10 through MS12 by implementing the closed loop control, processing the requisite materials, and demonstrating the minimum performance in the processed CF. As expressed by this reviewer earlier, the details of the closed loop control are thin but the importance of its capability appears to be critical to completion of the milestone. Successful implementation is expected during the next period of reporting. This reviewer looked forward to the completion of the economic evaluation to determine if the 50% reduction in LTC energy/cost can be realized.

Reviewer 5:

The reviewer noted that the proposed work is to complete the project by the end of FY 2019. MS10-MS12 are attainable, but this reviewer expects further delays in the generator commissioning and refinement.

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

Reviewer 1:

This reviewer said the project is highly relevant to the DOE objectives and addresses the immediate need of industry to find ways to reduce the cost of manufacturing CF.

Reviewer 2:

The reviewer asserted that this project addresses the urgent need for LCCF for lightweight vehicles. The cost reduction through low temperature electromagnetic carbonization is very creative and makes much sense.

Reviewer 3:

The reviewer indicated that the objective to lightweight transportation systems—to meet current and future goals for carbon emissions and fuel economy—hinge on the expanded use of high specific property materials. This will only occur if the manufacturing costs of those enabling materials, which include CF, are reduced. Clearly, this project is aimed at cost reduction of CF manufacturing. A potential 5% reduction in cost is significant and with it a reduction in total embodied energy furthers the goals of sustainability and reduced carbon emissions in and of itself. This is a project worthy of support.

Reviewer 4:

The reviewer commented that this project has high DOE relevance because it is directly addressing ways of reducing the energy costs of producing CF. The resulting fiber is demonstrated to meet DOE metrics. The challenges of the equipment seem to be gradually addressed and the partnership has potential to result in a commercially viable CF.

Reviewer 5:

This reviewer noted that currently, CF is too costly to use effectively on high volume vehicles. Any success in delivering lower cost CF will speed the introduction to high volume automotive vehicles.

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

Reviewer 1:

This reviewer said the project has sufficient resources to complete the project.

Reviewer 2:

The reviewer stated that the team has good resources through the large assets at ORNL in the CF space, and supporting technologies at 4X Technologies. The CPEC is being enhanced iteratively and seems to be providing positive results in the ongoing phases of the project.

Reviewer 3:

This reviewer remarked that collaboration with 4X Technologies leverages the resources and helps make the breakthrough. The project has accomplished much in terms of milestones and is on track.

Reviewer 4:

A very reasonable level of funding for early stage research work was observed by this reviewer. The capital-intensive component of this research is an important cost to bear. This reviewer might have expected some cost share from the partner of ORNL that will benefit from this research, with detail on the design and scaling of manufacturing equipment they can commercialize and sell to third party manufacturers. Additional contribution may lead to faster commercialization and impact DOE goals more quickly.

Reviewer 5:

This reviewer indicated that resources are likely to be insufficient, and explained that delays in equipment delivery and commissioning will undoubtedly require additional funding to complete this important project. The reviewer stated corrective actions should be identified to speed conclusion of this project.

Presentation Number: mat124
Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles
Principal Investigator: Xiadong Li (University of Virginia)

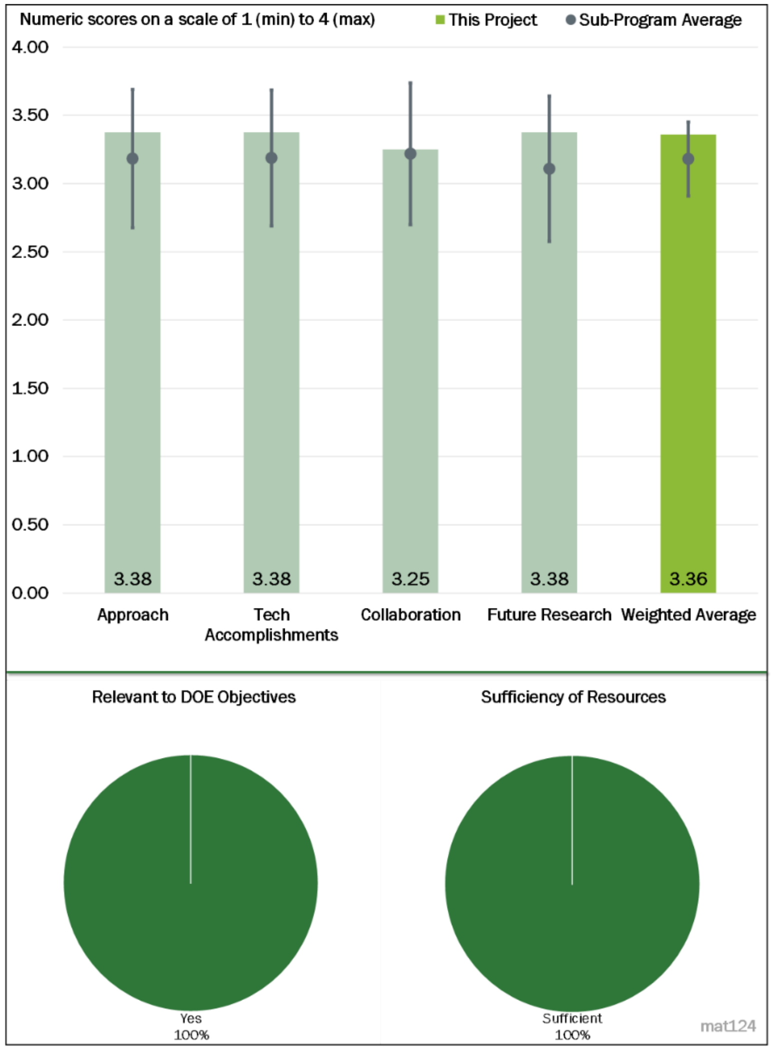

Figure 6-6 – Presentation Number: mat124 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles Principal Investigator: Xiadong Li (University of Virginia)

Presenter

Xiadong Li, University of Virginia

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer said the approach of the project is sound using the principles of ICME.

Reviewer 2:

The reviewer observed a very good approach. The team demonstrated several different components and "stepping stones" to modeling/predicting CF performance using "closed loop feedback." The presentation shows using PAN as baseline from precursor through processing to final CFs, which is a logical approach. It also showed several examples of where properties were close to model predictions. Other than cost for precursor fibers themselves, it is not clear what justified selection of nylon and polyethylene (PE) for candidate low-cost precursors as preliminary consideration of conversion costs (additional hours of time, use of sulfuric, etc.) calls these selections into question. However, these are good demonstration tools for new approaches. The proposed work to investigate various new processing approaches for converting alternative precursors into CF should provide insight into model prediction capabilities.

Reviewer 3:

The reviewer noted that the approach to this research on ICME is working well. However, the approach with experimental validation is very weak. The alternative precursor work will need reconsideration. The best PE-based CF surfaces show a flat cross-section which occurs when fiber is dominant with amorphous carbon. Graphene reinforcement will not be needed to achieve such mediocre performance.

Reviewer 4:

The reviewer reported the overall barriers identified by the team: weight reduction with lower density materials; development of an ICME predictive tool to optimize fiber processing parameters; and extending the ICME framework to include alternative precursors and novel manufacturing processes. It appears from the presentation that the Year 1 objectives of benchmarking the ICME for conventional PAN precursor-based CF are met to within 15% margin of error. The reviewer commented that progress made in Year 2 is towards alternate precursors based on PE and nylon. The team has conducted statistical analysis of alternative precursor oxidation, made progress on validation of simulation predictions, and initial mechanical testing of low-cost alternative fibers. The reviewer remarked the team has made progress on chemical conversion of alternative CFs. The team is also investigating large-scale simulations based on fiber mechanics to predict resultant properties. The reviewer observed very good progress in Year 2 of the program. Between the ICME and the experimental validations, the program may be attempting to do too much (i.e., ambitious), but this was just this reviewer's observation, not a criticism.

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

Reviewer 1:

This reviewer stated there is excellent technical progress achieving the predictions within 13% of experimental results.

Reviewer 2:

The reviewer asserted that the modeling data produced so far are great. The approach monitors pore evolution and how that can be controlled to enhance the performance in carbonized filaments. The ICME data matches well with experimental test data. On the experimental side stabilization of nylon with copper chloride (CuCl) is interesting. It was difficult to understand the claim of cost reduction of PE conversion via sulfonation. Oxidation is not needed but PE requires sulfonation. Not sure if the team thinks PE sulfonation is less expensive than oxidation in PAN.

Reviewer 3:

This reviewer said the accomplishments are good. The team has considered a variety of materials and approaches, also including additives and alternative processing techniques. Model progression appears to be on schedule. While the presentation cites nylon and PE as inherently low-cost products, this is widely known. The past year review suggested more attention to cost, which is worth mentioning again in terms of early decisions, acknowledging more in-depth economic analysis is planned for late project activities.

Reviewer 4:

This reviewer stated that the combined modeling-experimentation approach used is a very good one. The project team's ReaxFF simulations have been effectively used to study the effect of temperature, heat rates, fiber tension, etc., on resultant fiber chemical structures. The team uses the resulting structure to obtain input to AIREBO MD simulations of fiber mechanics. The reviewer suggested that it would be helpful to know what assumptions underlie the simulations and if perfect atomic/molecular structures are assumed. While 13%-15% variation to experiment is excellent, the reviewer asked what may be the underlying reasons.

In Year 1, the project team showed that it met/exceeded DOE goals in terms of the modulus and strength for PAN-based CF. In Year 2, the team showed that nylon-based CFs met/exceeded the modulus and strength goals set forth by DOE. The reviewer asked how predictable these are on a batch to batch variation—because CF production is inherently influenced statistically speaking—and how valid these results would be on a batch to batch variation, particularly with cost being a critical metric as well.

In Year 2, the reviewer reported that the project team has progressed to alternate precursors such as PE and nylon. While nylon showed the need for a long oxidation step, the team is looking at ultraviolet (UV) and related ways of reducing the time of oxidation while realizing high post-properties. This has significant implications on cost. The reviewer expressed interest in seeing the outcome of that part of the study. The reviewer asked what specific mechanism of graphene is enhancing the alignment and processability of the alternate precursors such as PE and nylon. While it was a good attempt to explain this, it needs more specific focus because it has a bearing on repeatability, statistically narrow band of properties, commercialization potential, and scale up. The reviewer also inquired about the cost implication of the graphene additive.

The reviewer further asked how the ICME is conducted to represent/capture the treatment with CuCl and resulting influence on processing. It was unclear what the carbon yield is from the alternate precursor such as PE and nylon, and how commercially viable it is. Overall, this reviewer observed excellent technical progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted an excellent collaboration between the University of Virginia (Lead), Pennsylvania State University, ORNL, Solvay S.A., and Oshkosh. The roles of the partners were well defined and articulated. The University of Virginia and Penn State are collaborating extensively on the molecular dynamics (MD) simulations, chemical conversion, and resulting mechanical behavior related to the complex modeling work. This reviewer reported that ORNL is conducting the experimental analysis of alternative precursors and large-scale pilot runs; Solvay S.A. is helping with the PAN fiber for baseline testing and industrial input to commercialization and of conventional and alternate precursor; and Oshkosh Corporation is providing industry insight on technology transfer leading to commercialization. All of these partners are playing a critical role, in this reviewer's opinion.

Reviewer 2:

This reviewer stated that there is good collaboration with academic universities, a National Laboratory, and an industrial partner.

Reviewer 3:

This reviewer noted that there are several pieces of work executed by multiple entities. The Penn State/University of Virginia modeling work seems to have some synergy. The reviewer inquired about who is doing PE sulfonation or nylon stabilization modeling.

Reviewer 4:

The reviewer commented that this project has assembled a good team with most members having substantial relevant experience, and activities are taking appropriate advantage of both the experience and diversity. The university modeling appears to be a strong point at the front end, and the plans for extensive trials at Solvay for model validation are key to establishing useful tools for others.

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:

This reviewer stated that the future work is well planned to meet the necessary project deliverables.

Reviewer 2:

The reviewer indicated that the proposed work to investigate various new processing approaches for converting alternative precursors into CF should provide insight into model prediction capabilities provided the team does not need to massage predictions to fit results. Now that both teams addressing ICME approaches for CF are well along pathways to respective project goals, it would be good to see specific technical exchanges in latter stages of the work to see if, for example, tools developed in this project provide successful prediction of fiber properties in the other project without compromising intellectual property or resource allocations for either team. It would also be useful to see some discussion on execution of technology transfer plans.

Reviewer 3:

This reviewer described the overall plan for proposed future research as logical and necessary. The Year 2 work is largely projected around alternate precursor work and building upon the ICME, processing, and testing results reported in the June 2019 review. Based on the Year 1 work, the team is looking to predict the various processing stages and resulting properties of the alternative fiber precursors.

The efforts to continue to optimize nylon and PE fiber production (treatment duration, temperature, graphene content, etc.) are very much on target. The mechanisms of the UV and related treatments to reduce the oxidation stage of Nylon fibers needs to be understood. The investigation of pre-treatment of the nylon precursor with CuCl is also very logical. The reviewer remarked while the Year 3 goals are rather ambitious, the validity of the Year 3 projections will really depend upon the extent of progress the team makes in Year 2.

Reviewer 4:

The reviewer noted that many plan details were not conveyed. The reviewer asked how Solvay will analyze costs for new precursors—they are not doing any experimental work.

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

Reviewer 1:

This reviewer remarked that the project is relevant to the mission of understanding the effect of various parameters in CF manufacturing on the outcome of fiber properties (stiffness and strength).

Reviewer 2:

The reviewer stated yes, this project supports DOE's objectives. CF is essential to deliver low-cost, light-weight materials for vehicle energy efficiency.

Reviewer 3:

This reviewer commented that the project demonstrated relevance to DOE. CF composites are key to light-weighting of vehicles for energy savings. The reviewer said in addressing cost and assessing alternative approaches, developing integrated computational tools will at least facilitate experimental optimization and hopefully help in up-front screening of major new methodologies.

Reviewer 4:

The reviewer responded positively that the DOE goals of reducing embodied energy of CF production, reducing cost, and attaining set modulus, strength, and strain metrics are largely being addressed in this project. While the team’s progress in ICME is commendable, the implications of cost, carbon yield, and possibilities of commercialization are less tangible—but that may be because the program is still in its initial third stage. Overall, the project is in line with DOE objectives.

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

Reviewer 1:

The reviewer indicated that the team has adequate resources across the collaboration. The University of Virginia and Pennsylvania State University are focused on the modeling efforts for which they are using the ReaxFF and large-scale AIREBO simulation tools, among others. The experimental partnership is provided by ORNL. The precursor supplier (Solvay) and the industrial partnership of Oshkosh are keeping the work real in terms of industrial outlook. These collaborations are well leveraged.

Reviewer 2:
The reviewer noted that the team has sufficient resources to complete the project.

Reviewer 3:
This reviewer described resources as adequate and well distributed.

Reviewer 4:
The reviewer observed resources that appear in-line both with progress and plans.

Presentation Number: mat125
Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber
Principal Investigator: Jeramie Adams (Western Research Institute)

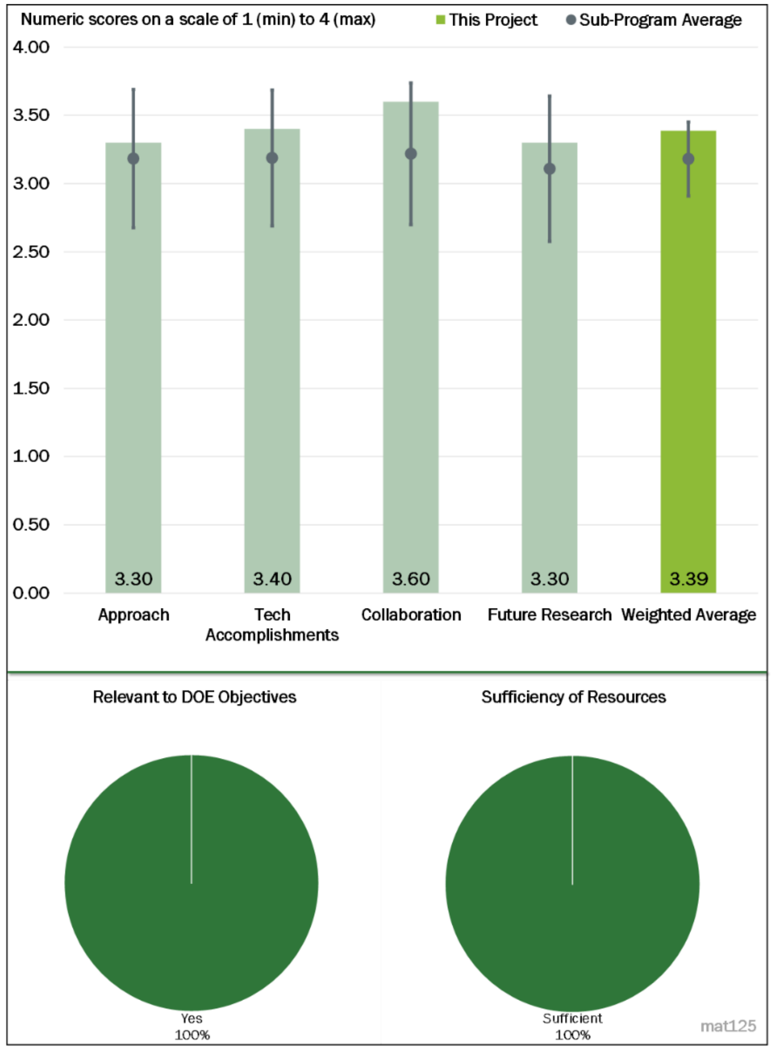

Figure 6-7 – Presentation Number: mat125 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber Principal Investigator: Jeramie Adams (Western Research Institute)

Presenter

Don Collins, Western Research Institute

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the project team consists of Western Research Institute, ORNL, Massachusetts Institute of Technology (MIT), Southern Research Institute (SRI), Advanced Carbon Products, LLC (APC), University of Wyoming, RAMACO, and Solvay with complementary expertise. The approach is novel and well designed and positioned to address the technical barriers.

Reviewer 2:

The reviewer commented that with an overarching goal to provide an ICME tool set to predict CF mechanical properties based on feedstock chemistries, the challenge is large, but this team has chosen an excellent approach through analysis of the three common feedstocks that make up the precursors of CF production. The chosen team made up of well qualified suppliers and analysts appear to be on a path that at a minimum will enable developers to understand impurity content, morphological, and molecular level evaluation and develop models to accurately predict properties. There is a satisfactory balance between data gathering and experimental work along with modelling and analysis.

Reviewer 3:

The reviewer stated the assembled team provides very good breadth of materials for consideration of LCCF feedstocks and it appears all identified candidates offer potential for downstream impact. What is not clear from the presentation is how the computational approaches are integrated to provide predictive tools to facilitate development and implementation.

Reviewer 4:

The reviewer observed a good approach. The three-pronged approach will compare and contrast different methods to creating the precursor for CF. The Approach would be stronger if technical cost modeling was explicitly included in each stream and to the ORNL and Carbon Fiber production and CF Tow production. There needs to be a clear cost per pound (or kilogram) target for the precursor to meet the final $5/pound CF tow cost.

Reviewer 5:

This reviewer noted that the work focuses on an ICME suite capable of predicting CF tow properties all the way down to the feedstock chemicals. Different types of approaches to producing CF are considered such as PAN-based, coal pitch-based, and petroleum pitch-based CF. The partnerships are structured based on the expertise of partners in these respective areas. They are looking to map high–volume, low-cost major feedstocks from petroleum, coal, and biomass relative to CF production and resulting mechanical properties. The project is ambitious and has numerous technical elements.

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

Reviewer 1:

The reviewer commented that this project is on track and in good shape. The team started with petroleum, coal, and biomass to derive CF that exhibited the mechanical properties that have met the DOE targets. The reviewer suggested that the team do more atomistic and microstructural characterization in terms of impurities and voids (size, distribution, and volume) and how they are related to the resultant mechanical properties.

Reviewer 2:

This reviewer remarked that the work completed to generate CF from three major upstream paths of feedstock is impressive and contains a good deal of work. The presentation showed a good understanding of the relevant information to pull from these three sources of precursor (biomass, petroleum, and coal). The conversion and reporting of properties, and outline of impurities and other physical properties, should support atomistic and micro-modeling of the precursor structure very well.

The question this reviewer wants to understand better relate to the reported properties in the review: Bio-acrylonitrile (Bio-ACN)—283 ksi strength, 36 MSI modulus, and 0.86% strain to failure; coal tar pitch (CTP)—361.3 ksi strength, 26.5MSI modulus, and 1.17% strain to failure; and petroleum pitch (PP)—347.9 ksi strength, 36.6 MSI modulus, and 1.18% strain to failure.

Given the general understanding that CF is extremely linear to failure, this reviewer offered the following suggestions. Firstly, Bio-ACN should have a strain to failure of 283E3 psi/36e6 psi equal to 0.79%, given the data variance is quite consistent with the reported strain to failure of 0.86%. This reviewer presumes that impurities are responsible for the low strength vis-a-vis the modulus, and asked if there would be strength improvements if the processing was driven to yield a lower modulus while preserving or improving fiber strength.

Secondly, CTP should have a strain to failure of 361300/26500000 equal to 1.36%, but the reported measurement of 1.17% suggests that impurities or defects lead to a lower failure strain than may be possible (or there was some strain hardening occurring). Overall, uniformity of the fiber is probably pretty good.

Thirdly, PP should have a failure strain of 347900/36600000 equal to 0.95%. Yet, the data suggest a 1.18% failure strain, or that either some yielding was occurring or (more likely) significant variance in fiber properties leads to filament breakage over a range of strains.

The reviewer's question remains as to whether this is insightful and/or useful as the team thinks about how to process each feedstock and tweak more performance. The reviewer asked if the team is able to tease out this behavior from the modeling; it would be a useful goal in this reviewer's opinion.

Reviewer 3:

The reviewer stated that a very large suite of materials has been proposed and are being assessed. Numerous materials already appear to meet minimum requirements while advantages and disadvantages are being well categorized. It appears at least several of these could be cost-effective candidates as well.

Reviewer 4:

This reviewer said that results from the different approaches seem to meet the modulus and strength metrics set forth by DOE. The strain for the bio-ACN is lower but the team is working to address that aspect. Many of the results presented in June 2019 were focused on bio-ACN feedstock and pitch. The work has an impressive spread across the various entities. The coarse grain models indicate greater than 70% predictions, which is very good at this stage of the project. However, it was not clear who is doing the computational modeling, and also what ICME tools are being used in the modeling work. Slide 11 had some cursory information and not sufficient to evaluate the depth of the ICME work. This is just an observation not a criticism. The technical progress has been very good overall.

Reviewer 5:

The reviewer stated that the progress and accomplishments are good. They are clearly presented. Slides 5, 6, and 7 would be improved if in the right-hand blocks there was a current estimated cost and a cost target for each of the three stages. The second-to-last 2,19 milestone should include technical cost modeling into the machine learning and process ranking. The technical accomplishments are strong. The CF produced from each of these precursors are meeting or close to meeting mechanical requirements. The reviewer wanted to see the cost status alongside of the modulus, strength, and strain metrics as well. The physical and chemical investigations are offering solid results. The reviewer asked how the processes could respond to "noise" in the original feedstock stream. Hopefully, one of the project's outputs will be the sensitivity and specification recommendations on the feedstock to ensure process robustness all the way to the final CF tow properties.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the team members have been collaborating to address simulation and experimentation challenges. The experimental part has accomplished much. More work should be focused on atomistic simulations on the atomic structure and carbon ring formation of CFs during each processing step. Pilot scale run should help the cost estimation.

Reviewer 2:

The reviewer commented that coordination appears to be strong across the team. There are multi-disciplinary efforts involved and selected team member working different aspects all coming together in what looks like a well-coordinated effort. It remains to be seen that the modelling and analysis is being fed upstream to yield improvements in feedstock preparation and conversion efforts, but the current trend looks promising.

The formation of an independent Advisory Panel is another commendable component of this effort. The panel is composed of significant stakeholders in the results and should benefit the coordination and re-direction (as needed) during performance of the balance of this effort.

Reviewer 3:

This reviewer noted that although there are a wide variety of organizations involved, with somewhat competing interests, it appears that the overall group is being well managed in heading towards common demonstration objectives.

Reviewer 4:

This reviewer stated the project has clear roles and responsibilities. The reviewer suggested that next year the PI add information regarding meeting cadence and attendance to Slide 13. This would strengthen the presentation of what is clearly excellent project management.

Reviewer 5:

The reviewer described the collaborating team and partner roles as well defined, with some questions about the partner role that was unclear. The reviewer reported that ORNL's role is in the bio-ACN, melt spinning, etc. The role of MIT and the Jeff Grossman Group is not clear to this reviewer, who inquired about how this team is involved with ICME. SRI's role is in the CAN; melt spinning of isotropic and mesophase CTP, PP, and gilsonite; and polymerization of bio-ACN with methyl acrylate and solution spinning. The reviewer also associated ACP with petroleum pitch work and Ramaco with coal pitch work. Solvay Composites was listed as an industry advisor. The reviewer asked about the University of Wyoming's role, which was stressed as unclear.

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 team has accomplished 45% of the proposed milestones. Future work has been well planned in a collaborative manner with regard to the decision points. The team may focus more on atomistic modeling to study the carbon ring formation mechanisms.

Reviewer 2:

The reviewer stated that the proposed work to scale up processing and produce CF for actual testing in composites will be beneficial for assessing fiber processing economics and useful data for commercialization assessment, although it will be more important to enhance the fiber-specific modeling objectives for the overall DOE goals for predictive tools. It is not clear that extensive modeling of composites mechanics is necessary.

Now that both teams addressing ICME approaches for CF are well along pathways to respective project goals, the reviewer said it would be good to see specific technical exchanges in latter stages of the work to see if, for example, tools developed in the other project provide successful prediction of fiber properties and processing optimization advantages in this project without compromising IP or resource allocations for either team. It would also be useful to see some discussion on execution of technology transfer plans.

Reviewer 3:

This reviewer said there is much work to do and the proposed path forward is very broad in terms of scope. What lacks might be detail; but given the presentation time the details of so much work is difficult to parse out in that timespan. This reviewer is most interested in seeing how this team closes the loop between modeling and data. There is a model validation phase ("Verify model simulation properties to actual produced material properties"), but there is no specific discussion on how deviations will be addressed nor specific mention of an iteration loop to close those differences.

This reviewer would have appreciated more detail regarding the relationship between the micro-scale (atomistic and molecular models) and the macro-scale finite element (FE) work to be applied. The reviewer asked if the FE work will be based upon data collected in testing or properties predicted by the micro-scale modeling.

Reviewer 4:

The reviewer described the projected future research as logical and necessary. This reviewer posed a number of questions and comments for the research team. Regarding scale up removal of impurities from CTP, the reviewer was unclear how much work is within this scope. Regarding scale up of mesophase CTP greater than 2 lb for CF production, the reviewer inquired about the barriers to get there and agreed with continuing physical and chemical characterization of intermediates/precursors/mesophase. Regarding further purification and modification of gilsonite to improve CF performance, the reviewer asked about the specific approaches that will help purify and modify the gilsonite.

Regarding slurry oil pitch and hot filtration of greater than 2 lb batches of PP mesophase, the reviewer had the same question as above, and agreed with chemical characterization of ACP 10 isotropic pitch. Regarding blending of PP isotropic pitch with CTP to produce hybrid mesophase, the reviewer asked why this would provide a more optimal material/process. Regarding bio acrylonitrile and scale up of bio-ACN production, the reviewer asked for the target scale up plan. This reviewer described optimizing polymerization of bio-ACN to produce bio-PAN as nebulous and asked how it will be optimized. The reviewer inquired as to how the strain will be improved to greater than or equal to 1%, and what mechanisms would enhance the strain. Understanding variability in bio-ACN product during production, the reviewer asked what methods would be adopted.

Regarding modeling and database, the reviewer referenced using modeling to identify the most stable intermediate and precursor molecules, then remarked that this aspect was not clear even during the June 2019 presentation. This reviewer identified a need to add more clarity to the modeling, underlying assumptions, process stages etc. The reviewer stated the same comment as above for the remaining tasks under modeling, and highlighted the following tasks: model pyrolysis formation of mesogen molecules from starting material molecules; model thermal reactions leading to crosslinking due to oxidative stabilization; verify model simulation properties to actual produced material properties; continue to apply and optimize machine learning; resin CF tow; and fabrication and macroscale modeling. Overall, the reviewer observed a very ambitious projected plan; it will be interesting to see the progress.

Reviewer 5:
This reviewer stated that there are clear next steps for the chemistry and processing. There are not clear future work plans for the technical cost modeling and the integration of energy and cost ramification to the various processing steps. Also, there are not clear plans for identifying and mitigating water or other impurities. The reviewer pointed out that these “noise factors” effect both mechanical performance and the cost.

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

Reviewer 1:
This reviewer said the project demonstrated relevance to DOE. Carbon fiber composites are key to light-weighting of vehicles for energy savings. In providing some good alternative precursors for consideration, the results could likely lead to alternative CFs for certain applications of interest.

Reviewer 2:
The reviewer noted that the project addressed alternate routes to producing LCCF. The cost elements are captured closely. All the partners are very knowledgeable in this area and the project is very relevant to DOE in terms of cost reduction of CF, and the resulting benefits.

Reviewer 3:
This reviewer said getting to LCCF tows directly supports the DOE objectives of reducing fuel consumption via lightweight actions.

Reviewer 4:
This reviewer said the project addresses the urgent needs of LCCF for light weight vehicles to reduce the overall weight 25%.

Reviewer 5:

The reviewer stated that development of alternative feedstocks and tools to predict the performance of those inputs for precursor and CF fiber conversion are critical to the drive toward lower costs for CF manufacturing and an expansion of the supply chain to meet the needs of power generation (in wind applications) and transportation needs to lower fossil fuel (carbon) emissions.

The reviewer commented that this work is foundational and should find application in other upstream feedstocks for CF manufacturing. With nearly 50% of the cost of CF bound up in the cost of PAN, this work is essential toward the overarching goal of CF cost/price reduction. It will be welcomed by industry.

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

Reviewer 1:

The reviewer noted that the team has used all available sources in each team member site that are critical to achieve the milestones in a timely manner.

Reviewer 2:

The reviewer noted that resources appear in-line both with progress and plans.

Reviewer 3:

This reviewer stated that with the long list of partners, collectively the team has excellent resources and assets in their R&D space.

Reviewer 4:

The reviewer indicated that resources appear to be sufficient. The spend rate is a bit low for the status of the project. Hopefully, the next year will generate more results due to a larger spend.

Reviewer 5:

While this reviewer has already remarked on the breadth of this activity, the overall funds would appear to be commensurate with this breadth. There remains a good deal of activity proposed for FY 2019 and only a smaller fraction of remaining funds applied, but less of this activity appears to be related to the expensive part of precursor and CF manufacturing and more to do with modelling and data analysis. It is something to be aware of, but should carry the team through completion. The reviewer remarked it might have been helpful to see where the balance of the funding will be applied to more accurately judge this risk.

Presentation Number: mat127
Presentation Title: USAMP Low-Cost Magnesium Sheet Component Development and Demonstration Project
Principal Investigator: Randy Gerken (Fiat Chrysler Automotive)

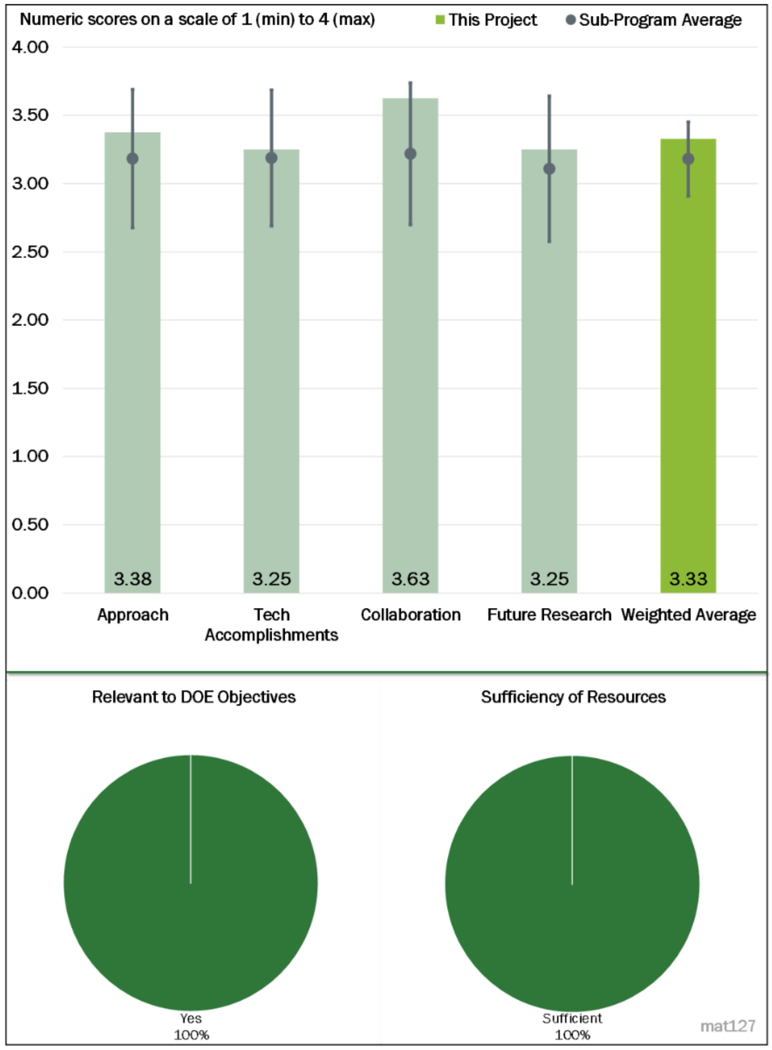

Figure 6-8 – Presentation Number: mat127 Presentation Title: USAMP Low-Cost Magnesium Sheet Component Development and Demonstration Project Principal Investigator: Randy Gerken (Fiat Chrysler Automotive)

Presenter

Randy Gerken, Fiat Chrysler Automotive

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a very impressive effort led by the U.S. automotive industry (Big 3) with a number of suppliers and university and National Laboratory partners. The ICME plan for prediction and validation of formability of magnesium (Mg) sheets is an important step. The overall plan and technical approach to addressing barriers is sound.

Reviewer 2:

The reviewer stated that a well-developed plan was presented providing detailed project tasks and milestones.

Reviewer 3:

This reviewer remarked that the progress in the project was well presented and all major conclusions drawn seem to be consistent. While the choice of E-Form Plus as the material for forming trials seems to be related to limited availability of alternatives in the required dimensions, more work can be done to further characterize experimental results on newly developed alloys. In this regard, a deeper understanding of the strange forming behavior of the new alloys at elevated temperatures would be beneficial.

Reviewer 4:

The reviewer noted that the project had already selected one alloy (E-Form Plus) for the experimental validation. This was not developed by the team and was provided by one of the industrial partners. Although three new alloys are being developed, this reviewer is unsure what the approach was in developing these new alloys. But the currently developed ones do not match the formability of E-Form Plus.

The reviewer pointed out that the presenter indicated that composition of E-Form Plus is protected and the new developments are vastly different from this. This approach does not seem to be beneficial. At least the microstructure, texture, and precipitate structure of the alloy E-Form Plus can be used as the starting point for the new alloys. As formability is based on these three microstructural features. Also, the warm forming is carried out at 250°C making it much more expensive. The reviewer commented cost benefit analysis needs to be carried out.

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

Reviewer 1:
This reviewer said that timely progress has been reported on key inputs including forming processing temperature, coil-applied coatings, lubricants, alloy, and pretreatment. The project appears to be on track relative to performance indicators.

Reviewer 2:
The reviewer remarked that excellent use of ICME capabilities were demonstrated, especially for solute dislocation interactions (atomostics), texture development, and formability modeling. The total number of alloys that are evaluated, however, are on the lower side. It is possible that more alloys were evaluated but only three were presented. The reviewer said coating/paint/lubricant and component development all show excellent progress.

Reviewer 3:
This reviewer stated that an elaboration of the characteristics of the new alloys would be beneficial.

Reviewer 4:
The reviewer noted that this project is to reduce the barriers for Mg sheet production. While the team had tested an existing alloy and chose to continue, the knowledge gained from the work did not contribute to future developments. Three new alloys, each different from one another, as well as the currently chosen one, are being developed using a very conventional approach. Some progress has been presented on the ICME approach for the effect of alloy elements, and precipitates on texture development.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer noted that all collaborations, roles, and responsibilities have been listed and described. The collaborative network for this project is very complex—clearly significant effort has been applied respective of project management to keep the projects aligned and on-track.

Reviewer 2:
The reviewer observed that this team covers most of the supply chain with the exception of North American material supplier. Monthly and quarterly meetings within the team make the communication and dissemination easier.

Reviewer 3:
This is a very large team and the reviewer commended the good coordination across such a multidisciplinary and multi-institution team.

Reviewer 4:
The reviewer commented that no major deficiencies were apparent.

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:
This reviewer said the decision points have been defined and are being executed in a responsible, coordinated way to ensure the project plan continues to move forward and meet the needs of all collaborative partners.

Reviewer 2:
The reviewer stated that all conclusions drawn with relevance to upcoming work were well judged.

Reviewer 3:
This reviewer said the proposed future research plans were adequate.

Reviewer 4:
This reviewer noted that continuing the forming experiments with the chosen alloy, as well as efforts to develop new alloys, are being proposed. The reviewer said the use of the information, which may be openly available, from the current alloy should be used as base for the new alloy development.

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

Reviewer 1:
This reviewer said that weight reduction is known to increase fuel efficiency as well as range for electric vehicles. It is proven that Mg can contribute to the target very easily. However, the cost of the material needs to be brought down and the current work can contribute towards this.

Reviewer 2:
The reviewer stated that Mg sheet can reduce the weight of multiple vehicle components, leading to gasoline displacement and an increase in energy efficiency.

Reviewer 3:
This reviewer said that while previous projects have identified the potential of Mg sheet respective of formability, this project has taken a more fully integrated approach to push the limits on door closure manufacturing by addressing identified technology gaps including Mg sheet alloy development, coil coatings, lubes, and pretreatment. There remains significant uncertainty that Mg sheet is a viable/sustainable material for the high volume manufacture of automotive closures; as such, there is considerable risk that the results of this project will not ever be implemented in the automotive industry.

Reviewer 4:
The reviewer remarked sufficient relevance is given.

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 appropriate resources for the stated tasks and milestones.

Reviewer 2:
The reviewer remarked that resources are sufficient.

Reviewer 3:
The reviewer stated that no insufficiencies were communicated.

Presentation Number: mat131
Presentation Title: Corrosion Control in Carbon-Fiber Reinforced Polymer Composite-Aluminum Closure Panel Hem Joints
Principal Investigator: Brian Okerberg (PPG)

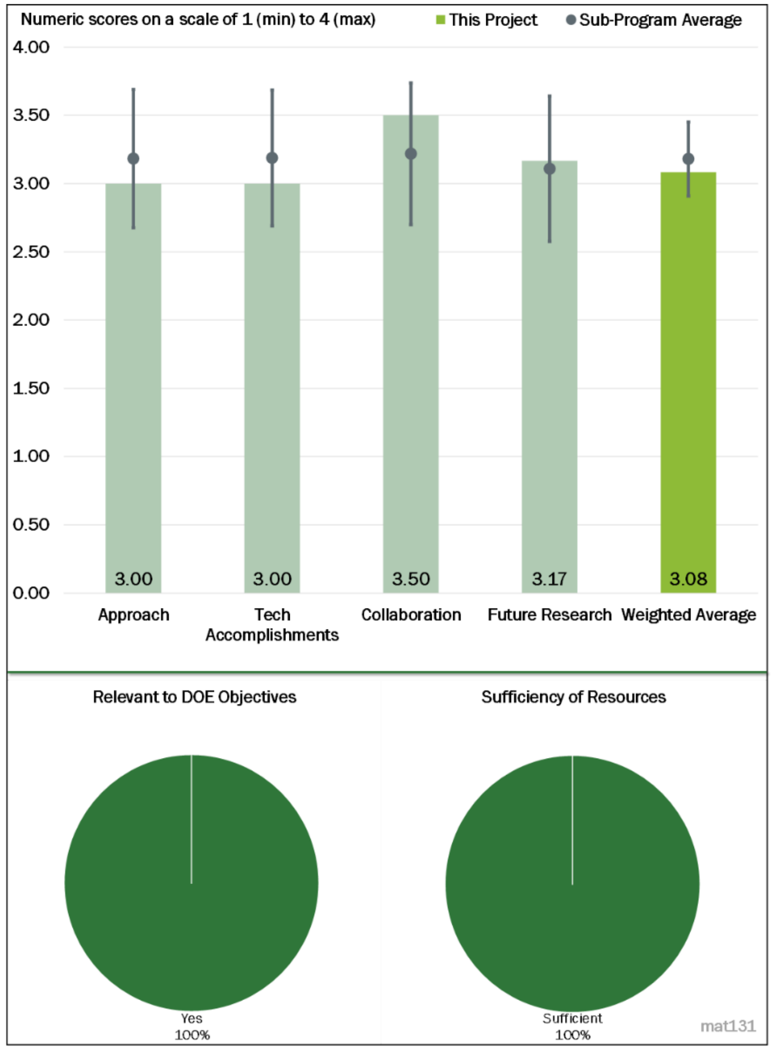

Figure 6-9 – Presentation Number: mat131 Presentation Title: Corrosion Control in Carbon-Fiber Reinforced Polymer Composite-Aluminum Closure Panel Hem Joints Principal Investigator: Brian Okerberg (PPG)

Presenter
Brian Okerberg, PPG

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
This reviewer said the approach of the present work is sound addressing technical challenges related to corrosion mitigation. It is not clear what experiments are planned to make the CFRP resin and adhesive withstand the paint bake temperatures.

Reviewer 2:
The reviewer highlighted that the project has several components, but was unsure if the hypothesis of this research is clearly communicated. The linking between predictive corrosion tests for lightweight materials to the types of CFRP and adhesives was very clear.

Reviewer 3:
The reviewer stated that the approach in addressing the technical work appears to be reasonable. One of the fundamental technical issues is the size of the coupon used. Extensions due to coefficient of thermal expansion (CTE) mismatch are a function of change in temperature, CTE of the material, and original length. A sample measuring 100 mm in length will move a lot less than a sample measuring 1,000 mm due to the same temperature excursion. The reviewer remarked the level of Al closure movement during bake process and its interaction with the adhesive during cure, and after cure will not be captured by the selected coupon geometry.

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

Reviewer 1:
This reviewer said that good progress is shown in determining the optimum primer formulations to meet the performance requirements.

Reviewer 2:

The reviewer remarked that the low temperature e-coat cure seems to be fine-tuned along with evaluation of the conductive primer formulation.

Reviewer 3:

The reviewer noted that this project has produced significant data that might be applicable to industrial part. The reviewer said the question still remains if the inter-relationship between adhesion-corrosion-CTE obtained via coupon tests translates to large part.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said there is excellent collaboration between a supplier, OEM, and academic partner.

Reviewer 2:

The reviewer commented that the results show good communication between all team members.

Reviewer 3:

The reviewer stated that collaboration among project members appears reasonable.

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 described the future work as well laid out. Decklid (liftgate) assembly is an excellent candidate for demonstrating the developed technology.

Reviewer 2:

The reviewer noted the future research proposed here will deliver the key applicable data.

Reviewer 3:

This reviewer said the proposed future research requires a bit more detail. For example, the reviewer asked how many prototypes will be built, what type of CF and Al substrates will be used, and how the corrosion performance of the final assembly will be evaluated.

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

Reviewer 1:

The reviewer noted that the technology explored in this project has great relevance to accelerate implementation of CF composites. Currently, achieving Class A finish requirements for CF composites is a significant challenge, and due to that an Al outer is a good choice at this time. The reviewer remarked technology to mitigate the corrosion with Al outer and CF inner is critical.

Reviewer 2:

This reviewer stated that corrosion mitigation and CTE mismatch of dissimilar materials are extremely important to understand for future lightweighting initiatives.

Reviewer 3:

The reviewer remarked that lightweight CFRP materials joining with Al is very important for commercialization of CFRP.

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

Reviewer 1:
Sufficient resources to complete the project were observed by this reviewer.

Reviewer 2:
This reviewer stated that based on the presented work, the resources are efficiently deployed.

Reviewer 3:
The reviewer asserted that resources are adequately distributed, and milestones are well-planned.

Presentation Number: mat132
Presentation Title: High-Strength Steel-Aluminum Components by Vaporizing Foil Actuator Welding
Principal Investigator: Glenn Daehn (Ohio State University)

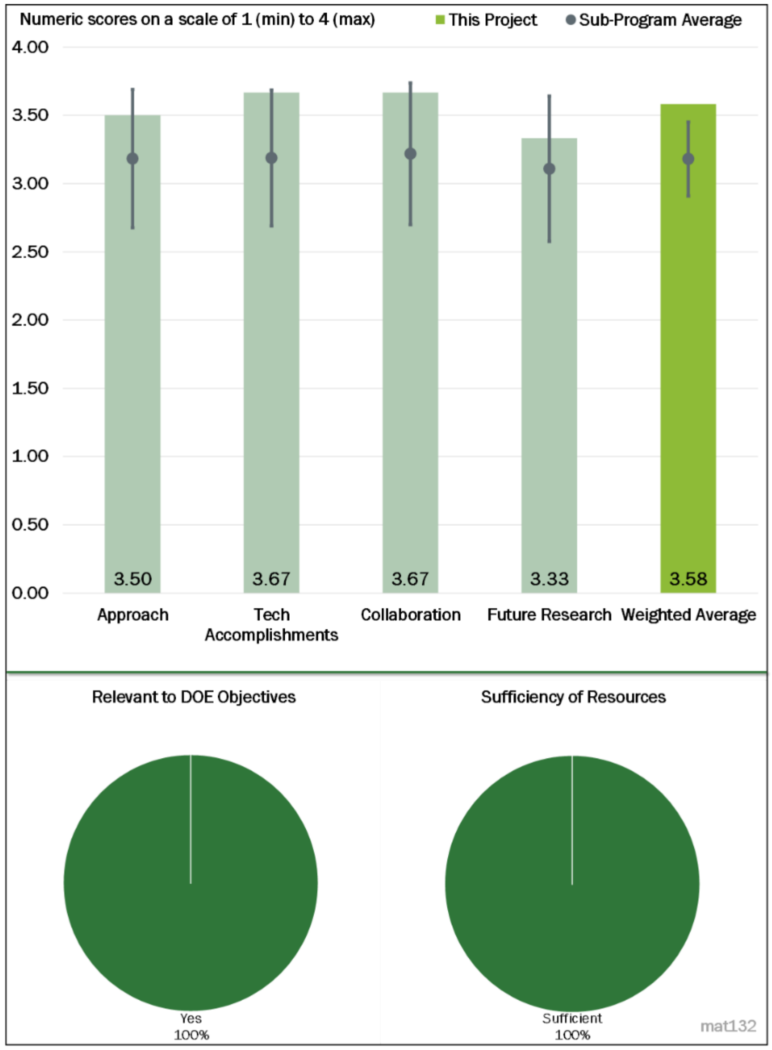

Figure 6-10 – Presentation Number: mat132 Presentation Title: High-Strength Steel-Aluminum Components by Vaporizing Foil Actuator Welding Principal Investigator: Glenn Daehn (Ohio State University)

Presenter
Glenn Daehn, Ohio State University

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
This reviewer commented that the approach uses a well-developed technology for joining dissimilar metals and is currently addressing the pre-production phase through process and tool development. The end goal is to produce a prototype structure to test against the current industry requirements for a similar part fabricated with a single metal. The approach is also considering characterizing the microstructure of the welds and modeling the data collected to improve the welding process and final component assembly. The reviewer said the approach is excellent because it considers process development, analysis, and modeling of weld structure and component assembly and test. There are still some remaining barriers to address that add risk to the completion of the effort.

Reviewer 2:
This reviewer remarked that the approach and milestones are well-laid.

Reviewer 3:
This reviewer said the approach is generally good and will answer many of the questions posed. A few things for the PIs to consider include considering and analyzing quantification of strains across the weld interface. There is currently no plan to do this. The engine seat/support is a load bearing component subject to stresses. The reviewer remarked strains across the weld fusion line and across materials will affect the performance and durability of the component. The possibility of this part corroding and/or failing by fatigue makes this evaluation important.

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

Reviewer 1:

This reviewer noted the project is in its fourth and final year of execution. Much of the work in the first three years have contributed significantly to the success of this project, including automobile structural component screening and selection for prototyping, weld and weld process characterization, weld sample configurations and testing, improvements to an automated welding equipment, development of a weld head capable of welding all configurations, and development of a welding process that uses robotic control for efficient and cost effective welding for mass component fabrication. The reviewer said the process and structures have been computationally modelled to capture weld characteristics and temperature effects to link material properties to structure. The results presented for all these efforts demonstrate some outstanding technical accomplishments for dissimilar material welding and process development.

Reviewer 2:

The reviewer stated the technical accomplishments will contribute towards achieving the set goals of this project. However, it will be prudent to analyze the strains across the fusion line of the welds into the Al and steel materials to make sure these welds will be durable and will not be unduly affected by high and multi-directional strains, which can adversely affect the longevity of the part under consideration.

Reviewer 3:

The reviewer remarked that accomplishments are in line with the phase of the project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer pointed out that the project exhibits outstanding collaboration and coordination amongst seven team member organizations. Project team members are from industry (equipment and material suppliers), academia, and a DOE National Laboratory. Each partner's efforts are well-defined and integrated in the overall project schedule.

Reviewer 2:

The reviewer remarked that the team appears to be solid and well-rounded with complimentary skills.

Reviewer 3:

This reviewer said the collaboration is sufficient among project team members.

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

Reviewer 1:

The reviewer indicated that the proposed future research for the remaining portion of the project (four months) will require an ambitious effort to maintain the project schedule to address the six areas to be completed. Because the project has successfully completed previous tasks and met all milestones, the project will probably address the remaining research needs successfully also.

Reviewer 2:

The reviewer requested that the project team consider comments made in the approach and technical accomplishment sections about high strains across the weld fusion line and into the dissimilar materials (especially if multi-axial/multi-directional) in reviewing the direction of future work.

Reviewer 3:

This reviewer suggested also establishing targets for CAE correlation at the component level. In addition, it would be great if assessment of joint thickness evaluations can also be performed at the component level to better understand the relationships between how the full assembly is fixtured and the order at which the different joints are formed, and be able to match the actual joint areas in the full assembly versus the joint areas modeled using CAE.

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

Reviewer 1:

This reviewer noted that the project is intended to reduce the weight of a structural component used in a 2016 mid-size sedan by 20% with a $3/lb cost savings. The DOE requirement is for a 25% weight reduction for a 2012 mid-size sedan with a $5/lb cost savings. Because the overall weight of vehicles has decreased between 2012 and 2016, the requirements being demonstrated in this project will certainly meet or exceed the DOE targets.

Reviewer 2:

This reviewer said the work is important to the development of dissimilar metal welds for auto body construction, which is important in reducing auto glider weight.

Reviewer 3:

The reviewer stated that this is certainly a novel joining technique, and the outcome of the project will further explore the fit of such joining for automotive applications at a larger scale.

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

Reviewer 1:

The reviewer noted that this project was funded $2.4 million over a 4-year period (an average of $600,000 per year). The project addressed all aspects for commercializing a vaporizing foil actuator weld technology and the industrial process for using this welding method. The reviewer said the funding included a small amount of industry share and involved six participating organizations. The funding, personnel, and facilities are enough to complete the annual tasks and meet all milestones during the overall performance period.

Reviewer 2:

The reviewer observed resources that appear to be efficiently used.

Reviewer 3:

The reviewer stated the resources appear to be adequate. However, it is hard to say because there is no information about how much has been spent of the budget.

Presentation Number: mat133
Presentation Title: Corrosion Protection and Dissimilar Material Joining for Next-Generation Lightweight Vehicles
Principal Investigator: DJ Spinella (Arconic)

Presenter
DJ Spinella, Arconic

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

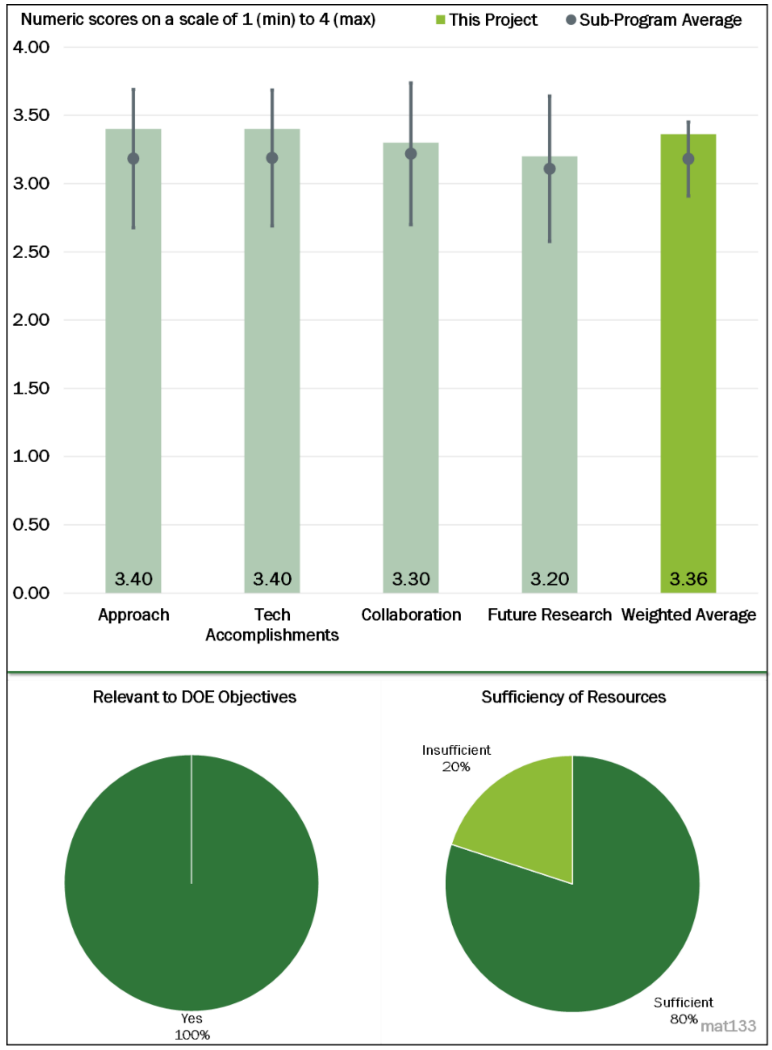

Figure 6-11 – Presentation Number: mat133 Presentation Title: Corrosion Protection and Dissimilar Material Joining for Next-Generation Lightweight Vehicles Principal Investigator: DJ Spinella (Arconic)

Reviewer 1:
The reviewer observed that the approach for the overall project addresses all technical barriers identified by DOE for corrosion of joints using dissimilar materials. From the start of the project through its completion (one year from the date of the AMR), the material combinations, components, and testing are properly defined for a well-known joining method of resistance spot riveting. The approach includes all aspects from material selection through production strategies which will improve the ability to commercialize the process.

Reviewer 2:
The reviewer stated that the project evaluates mechanical strength before and after accelerated corrosion exposure (through three different accelerated corrosion procedures) for several dissimilar material joints, and compares results with those of dissimilar material joint combinations produced by two alternative commercially available joining processes (flow drill screw [FDS] and self-pierce rivet [SPR]) and evaluates high volume manufacturing concerns (angularity, gap, etc.) and proposes robotic demonstration structure assembly and evaluation.

Also, the technology proposed in the project allows for use of the most commonly used existing high volume manufacturing process (resistance spot weld) equipment, thus substantially improving the chances of the technology being implemented into high volume manufacturing operations in the near future.

Reviewer 3:
This reviewer stated that multi material joining and its performance is the focus. By using the most widely used material as well as future possible materials (7000 series Al alloy) the project is focusing on the most

important aspects of the lightweighting. The reviewer said the experimental work is well planned with various combinations of materials, stacking order, and rivet types. The mechanical and corrosion performance are evaluated.

Reviewer 4:

This reviewer said that an excellent presentation of the progress was given during the AMR. A topic that was not discussed was how the different joining techniques respond and mitigate differences in thermal expansion coefficients of the dissimilar materials. This is an important consideration during the paint drying process in the automotive industry.

Reviewer 5:

The reviewer noted that corrosion testing is on as-joined coupons, though certainly the Al-steel couples would be run through E-coat. This reviewer suggested including this as baseline of corrosion mitigation strategy. The project target is to measure corrosion extent, however, their observation that orientation of the coupon in the environmental chamber highlights a need to investigate the differences in electrochemical potential of various couples in the joint as this is the driving force for corrosion. Consider this as part of the work in corrosion mitigation strategies. Another consideration would be including joints at the extremes of rivet angularity and gaps.

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

Reviewer 1:

The reviewer remarked that the work to date is excellent. While the project has been delayed, the work reported at this time is substantial and the additional time spent on corrosion performance evaluation and production process limitations should be well spent. The substantial attention to detail on corrosion evaluation is especially appreciated.

Reviewer 2:

The reviewer observed that good results have been obtained for corrosion tests using standard test procedures (ASTM B117) on the various materials (steel, Al, and CFRP with and without an adhesive) in different configurations. Discovery was made for the impact of sample orientation in the corrosion test chamber, which could change the procedure for future corrosion testing. Data presented for offset, angular, and shimmed production configurations showed good results for all materials used. Test results were also good for various rivet hole sizes, rivet lengths, and orientation for the parts that were joined using resistance spot riveting. The reviewer said these accomplishments contribute significantly to the success of commercializing the joining method and process.

Reviewer 3:

This reviewer said the progress made is in line with the project plan.

Reviewer 4:

Satisfactory progress was observed by this reviewer. Various combinations of materials have been fabricated using the joining method. The mechanical performance and corrosion are being evaluated. Based on the current presentation it appears the joining method can be successfully used for multi-material joining. Also, the team has understood the challenges in stepping up the process to production. But most are technical in nature and with adequate attention these could be accomplished.

Reviewer 5:

The reviewer praised the good job on investigating the process robustness regarding rivet angle, etc. The reviewer remarked it is not clear what the go/no-go metrics for the feed system repeatability are, which is Q2 2019. It would have been appropriate to address this topic given the timing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer noted that effective collaboration was demonstrated between a materials manufacturer/supplier and an OEM, with participation from a university to quantify corrosion levels and characterize the adhesives and coatings used for protecting the joint from corrosion. Each participant's responsibility was well defined and the project is executing in a very coordinated manner. The fact that an OEM was involved at the beginning of the project and will be involved in testing the riveted samples will contribute to acceptance of the process by the OEM.

Reviewer 2:

This reviewer stated that good collaboration was demonstrated between the sheet Al supplier Arconic, the OEM Honda, and academic researchers at The Ohio State University (OSU). Arconic is focused on developing the joining process, and OSU and Honda are focused on corrosion evaluation. The work seems to be allocated appropriately to take advantage of each partner's strengths.

Reviewer 3:

The reviewer noted that the team consists of one material supplier (Al), one OEM, and one university; this team can address most of the technical issues and can be considered adequate. The progress report indicates proper communication and exchange of knowledge among the team members (even though the presentation does not address the nature of technology transfer).

Reviewer 4:

The reviewer remarked that project coordination appeared to be good.

Reviewer 5:

This reviewer commented that there is a clear split of responsibilities along core competencies between partners. It would have been good to have included either a system integrator or equipment OEM in the demonstrator deliverable as a partner.

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:

This reviewer indicated that all proposed future work seems appropriate for the intended production implementation of the process technology. Because previous and current work has identified and quantified galvanic corrosion issues, then continued evaluation in this area and determining mitigation strategies are the appropriate next steps. Additionally, now that production process condition limits have been identified, the next planned steps of establishing feed system repeatability and manufacturing demonstrator part and assemblies with robotic assembly are the obvious and appropriate next steps. Overall, this seems to be a well-planned project.

Reviewer 2:

The reviewer stated that the work plan next FY is good with more industrial level testing. Development of an isolation system to reduce the galvanic coupling is a good approach. Earlier work on Mg-Al joints should be reviewed while developing this. The reviewer said production of sub-assemblies and testing is also included. However, whether this could be achieved in the given timeline is doubtful.

Reviewer 3:

The reviewer noted that the proposed future research and testing for the remainder of the project will address all concerns that the OEM may have regarding corrosion of joints in all configurations, limits on process and production conditions, and the demonstration of parts manufacture and assembly. Other challenges for resistance spot riveting were identified that go beyond the performance period and funding for the current project (e.g., riveting of thicker materials and strength and corrosion resistance for high-volume, full manufacturing).

Reviewer 4:
This reviewer said the proposed work is okay.

Reviewer 5:
This reviewer said the use of the term "EL of the process" is not a common term, and as such "EL" should be spelled out. There was no mention of any remaining challenges or barriers with CFRP containing joints. There appeared to be no plan in the current work to investigate why the resistance spot rivet (RSR) strength after 10 days of corrosion increases significantly then drops again after 32 days—yet SPR or FDS do not exhibit such behavior. The reviewer said there appears to be no plan to address the fundamental reason for differences in corrosion with orientation in environmental chamber.

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

Reviewer 1:
The reviewer stated the project directly supports the overall DOE objectives for multi-material joining processes. Corrosion is a significant factor when dissimilar materials are used to form structural components for automobiles. Material cost and ease of production are also considerations. The work done during this project addresses the barriers and challenges defined by the DOE VTO.

Reviewer 2:
This reviewer said the project supports the overall DOE project objectives by addressing the critical need to join high-strength Al and steel alloys together, and to validate high volume manufacturing process capability on a demonstration component and evaluate susceptibility to galvanic corrosion (a critical concern with dissimilar metal joints) by evaluating structural performance both before and after exposure to an accelerated corrosion environment.

Reviewer 3:
The reviewer stated that use of various lowdensity materials including Al, composites, and Mg is necessary for lightweighting of vehicles. This approach is known to save fuel or improve the range in EVs. This project is developing the most common joining process, riveting, for multi-material assembly involving Al, steel, and CF composites. If the joining process is proven to be effective without compromising the corrosion performance, then the potential for lightweighting at a reduced cost could be realized.

Reviewer 4:
This reviewer noted that the project targets strategic lightweight materials, addresses the strategic focus area of dissimilar material joining and corrosion, and supports 10%-20% mass reduction over all steel joint design.

Reviewer 5:
The reviewer stated that for lightweighting, multi-material joining technologies will be a key technology.

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

Reviewer 1:
The reviewer noted that the total performance period is 3.5 years and total funding is $2.4 million, which is about $685,000 per year for three participants (an average of $228,000 per participant per year). This is sufficient funding and sufficient resources (personnel and facilities) to complete the project successfully.

Reviewer 2:

The reviewer commented that resources appear to be appropriate for the scope of the project, and the accomplishments to date seem to support this.

Reviewer 3:

This reviewer noted that no shortages in resources were communicated.

Reviewer 4:

This reviewer said that based on funding from Slide 2, the available funding for 2019 would be approximately $500,000. This seems low given the project continues to Q2 2020 and the project has yet to do corrosion mitigation strategies and demonstration.

Presentation Number: mat136
Presentation Title: High-Performance Computing and High-Throughput Characterizations towards Interfaces-by-Design for Dissimilar Materials Joining
Principal Investigator: Xin Sun (Oak Ridge National Laboratory)

Presenter

Xin Sun, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

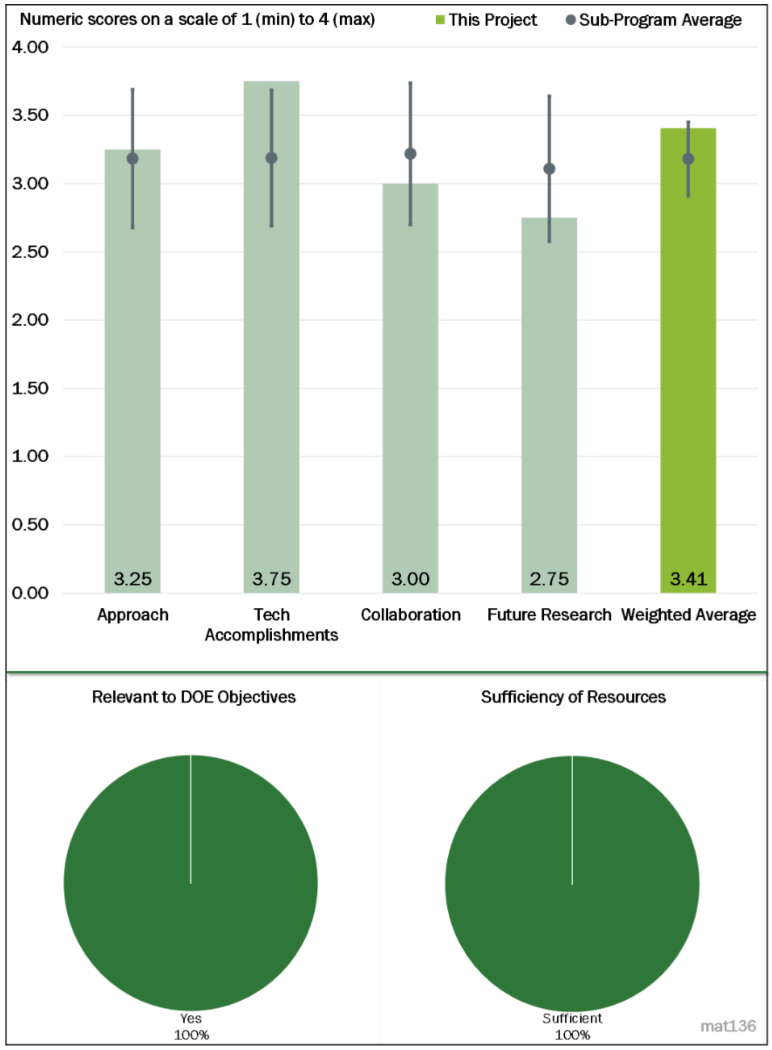

Figure 6-12 – Presentation Number: mat136 Presentation Title: High-Performance Computing and High-Throughput Characterizations towards Interfaces-by-Design for Dissimilar Materials Joining
Principal Investigator: Xin Sun (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the project started in October 2017 and is scheduled to end in September 2020. The approach is strong, which this reviewer reported as developing a validated forward computational model for multi-material joints and running it in inverse mode to design the geometry and area of the interface required to achieve a certain strength. The PI/co-PI use experimental data supplied by the rest of the team. One concern area is the T-peel tests, which as correctly pointed out by the presenters is problematic (due to combined loading and asymmetry). The reviewer pointed out that shear tests or cross-tensile tests were suggested as a means to isolate shear or normal tension modes.

Reviewer 2:

The reviewer indicated that the general interface by design approach is clear but how that is applied to the various processes/material combinations is not clear. The slides could significantly benefit from either an overall project plan with deliverables and timing or a visual flow chart. On Slide 11 it is not clear the relative effects of lateral velocity and temperature. The reviewer asked if temperature via surface modification was pursued just because it was easier to implement.

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

Reviewer 1:

The reviewer noted that the team has made progress in developing the model for Mg-steel for various joining processes. In general terms, the model is doing a good job capturing the main trends of the experimental measurements.

Reviewer 2:

This reviewer stated that the use of Mg/iron (Fe) impact welding to complete the molecular dynamics simulation and then apply that to the Mg/Fe ultrasonic welding (USW) process development shows great use of resources and flexibility with excellent results. Now the team just needs to do the same to Mg/Fe friction stir welding (FSW).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said there is very strong collaboration across the board involving experimentalists and the computational team at ORNL, Pacific Northwest National Laboratory (PNNL), and Argonne National Laboratory. Technology transfer and publications substantiate the effort.

Reviewer 2:

This reviewer said that because there are a number of other projects which are feeding into the Interface by Design project, a slide providing the overall view of interrelationships should be included. Molecular dynamic simulation was the focus on the work presented. However, it is not clear whether interface by design will limit itself to interface strength only or if it will also include geometrical aspects. If so, then why not investigate the interface strength of Mg/Fe and Mg/Mg-zinc (Zn) eutectic/Fe because this was clearly identified as significant in MAT138 project. Once that is identified, define the optimum interface in order to provide direction to achieving such in MAT138.

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:

This reviewer said that the plan presented makes sense. As noted, the experimental effort that feeds the computational model could benefit from a more formal understanding of process-property relationships (via design of experiments) as well as improved testing isolating the failure modes such as shear, cross-tensile tests, etc.

Reviewer 2:

This reviewer said that without a clear overall picture of this project and its inter-relationship to the related process projects it is difficult to assess what the appropriate decision points are. This reviewer is missing the plan on Mg/Fe interface by design simulation and the ongoing Mg/Fe FSW work. The reviewer strongly encouraged exploration into the other interface combinations such as supporting MAT137

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

Reviewer 1:

The reviewer noted that this project targets strategic lightweight materials, and addresses the strategic focus area of dissimilar material joining.

Reviewer 2:

The reviewer remarked that the computational tool developed could be used for various material combinations, though this is a long-term endeavor given the complexity and dimension of the problem.

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

Reviewer 1:

This reviewer commented that resources are sufficient and the team exhibited great motivation by investigating the Mg/Fe impact welding interface and applying that to USW.

Reviewer 2:

The reviewer indicated that resources to perform the research are sufficient as presented.

Presentation Number: mat137
Presentation Title: Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel
Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Presenter
Yong Chae Lim, Oak Ridge National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

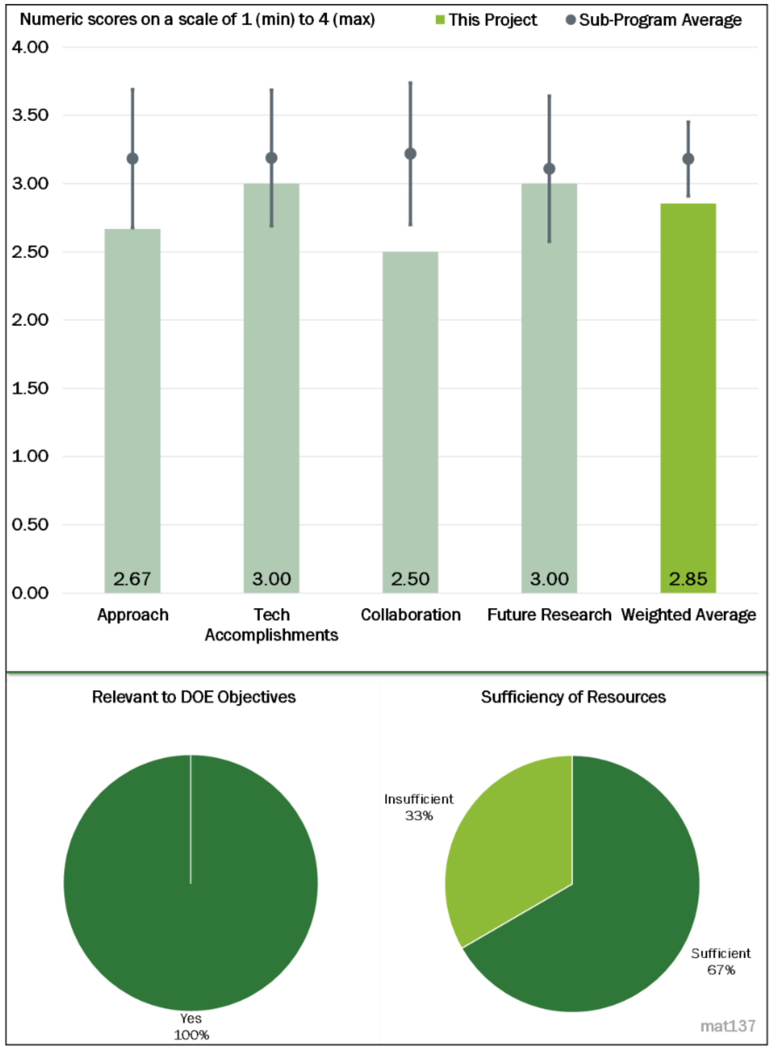

Figure 6-13 – Presentation Number: mat137 Presentation Title: Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked that this program is an important area that has great technical leverage. There are great tools being used and available to the team. There is not a clear focus on a key scientific or technical question. The experiments seem scattered and there is not clear articulation of what benefit there would be if the program were fully successful. It would make the work much more useful if the exact adhesives used could be disclosed.

Reviewer 2:
The reviewer stated that the approach appears to contain many elements containing different adhesives, different plastic substrates, and surface preparation. It would be good to narrow the scope to a narrower selection of variables for successful outcome of the project. The project objective summary describes bond performance, joint design, and lifetime predictions—but the actual content of the project deliverables deals very little with lifetime predictions and joint design.

Reviewer 3:
This reviewer commented that Slide 5 is given as the overall plan, but this is just a table of inter-relationships and not a plan. An entire lab could be applied to investigate everything on Slide 5. The plan should clearly spell out the adhesive/polyphthalamide (PPA) matrix as typically there is a resin rich surface layer which the adhesive bonds to. The reviewer asked how the team is going to investigate that and how Interface by Design is going to play a role. The plan should clearly spell out the exposed fiber/PPA matrix post sanding or ablation.

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

Reviewer 1:
The reviewer stated that the technical accomplishment seems reasonable.

Reviewer 2:
This reviewer noted that Slide 8 includes non-destructive evaluation acoustic analysis as part of the plan, but the reviewer saw no work related to this. Good work on the interface investigation using analytical tools as well as simulation.

Reviewer 3:
The reviewer remarked that the digital image correlation and microscopy results are good, but do not seem sufficient given the size and budget of the program.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer pointed out that Slide 5 provides a very clear picture of the inter-lab collaboration. However, an overall project plan with activities/deliverables/timing would be helpful.

Reviewer 2:
The reviewer noted that it appears the right players are involved. It is not fully clear exactly what partner is carrying out each activity nor how this is becoming an integrated whole.

Reviewer 3:
The reviewer indicated that the collaboration with the Interface by Design team is not very clear. Perhaps the scope of the project activities and details affect the collaboration needs, but at the moment the collaboration appears disjointed and not aligned with the overall project objectives.

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

Reviewer 1:
The reviewer remarked that details of the future proposed work are well-laid out. However, the interaction with adhesive suppliers or selection of adhesive suppliers in understanding the role of adhesives properties is not well-articulated for the proposed future research.

Reviewer 2:
The reviewer stated the ultimate measure of success is not made clear and should guide future research. It should either be based on assessing a clear technical hypothesis, or provide data that industry would find useful. It is not clear the path achieves either objective.

Reviewer 3:
This reviewer noted that the proposal is surface modification. However, it is missing proposed work which would take advantage of the interface analysis/diffusion and simulation. On Slide 14, the reviewer asked which interface is best and how to achieve that. There is already significant work on surface modification processes for adhesive bonding. What is really lacking is a fundamental understanding of what is happening at the adhesive/CFRP interface and how that is affected by environment (moisture), which is critical since industry would typically need to introduce a peel stopper in conjunction with the adhesive.

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

Reviewer 1:
The reviewer commented that improved multi-material bonding strategies are essential. This addresses a key area.

Reviewer 2:
This reviewer stated that joining of dissimilar materials and fundamental understanding is extremely important for future acceptance and mitigation of technology barriers.

Reviewer 3:
The reviewer noted this project targets strategic lightweight materials, and addresses the strategic focus area of dissimilar material joining.

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 a well-funded program for the objectives.

Reviewer 2:
This reviewer stated the resources appear to be efficiently deployed in supporting the project objectives.

Reviewer 3:
Without an overall plan with activities, deliverables, and timing, this reviewer cannot comment on whether or not there are sufficient resources available or not. The reviewer cannot tell how many adhesive systems are included or how many substrates are to be included.

Presentation Number: mat138
Presentation Title: Solid-State Joining of Magnesium Sheet to High-Strength Steel
Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

Presenter

Piyush Upadhyay, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

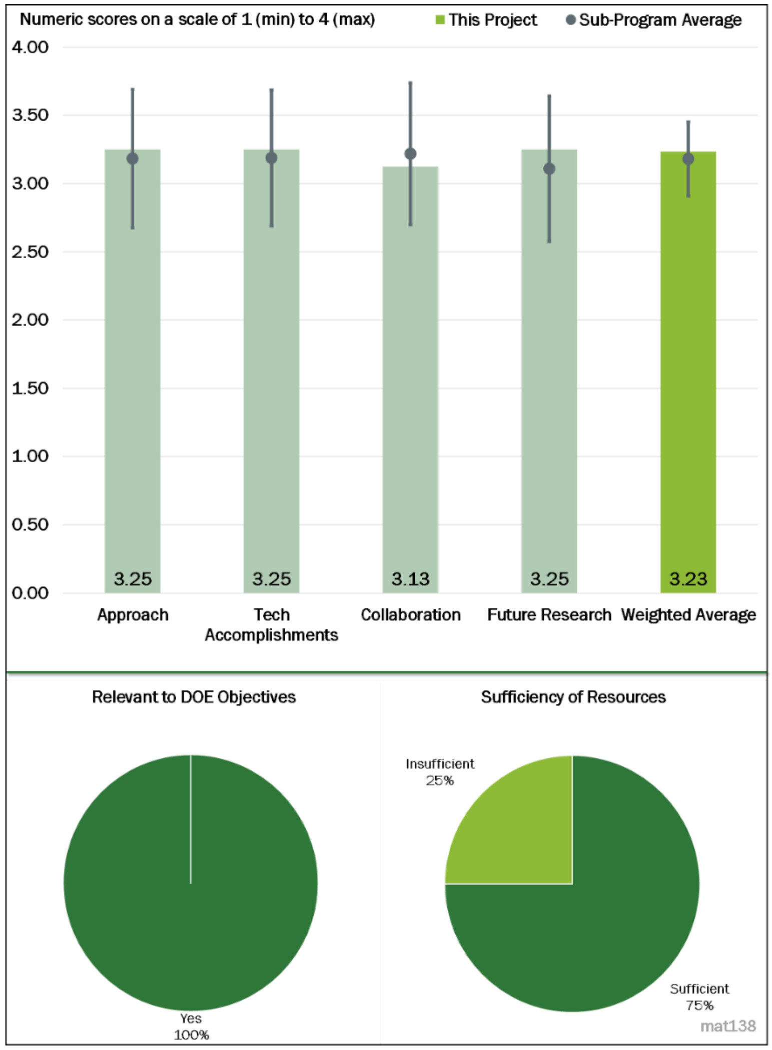

Figure 6-14 – Presentation Number: mat138 Presentation Title: Solid-State Joining of Magnesium Sheet to High-Strength Steel Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer noted the project addresses the fundamental aspects for two well-known techniques for joining Mg and steel. Much research has been done previously but a thorough analysis of resulting welds has not been done. The approach correlates various process parameters and variables to the interface chemistry and properties of the welds to maximize strength, ductility, and corrosion resistance. Both the proven technologies for joining Mg and steel and the maximization or optimization of the resulting weld are challenges for meeting DOE VTO requirements of multi-material joining.

Reviewer 2:

The reviewer said this is an interesting and comprehensive approach to an important problem. Much very clear and careful micro-level analysis is informing joint formation and this is laudable. The program seems a little short on solid-mechanics modeling to pull together a complete understanding of weld performance.

Reviewer 3:

This reviewer noted that the project addresses a difficult problem (joining Mg and steel), hence it attempts to mature solid-state joining techniques to the point where robust joints are achieved. FSW and USW were downselected as of September 2018, and the effort since then has included a study trying to correlate process parameters with interface properties and chemistry. The current effort as presented maps the mechanical properties across the interface utilizing nanoindentation, mechanical testing, and feeds the “interface by design” effort. The presentation did not discuss in detail what process parameters are being evaluated for each process and how the correlation is being formally investigated. The reviewer said it would be useful to include a table showing process parameters and the parameter space that is being covered in the study.

Reviewer 4:

The reviewer noted that there is a general approach description (correlate interface chemistry with process parameters and tailor joint interface to get best results). However, what this reviewer did not see is a target for what the optimum interface chemistry is and process maps indicating the direction to dial in the various process parameters. Also, the reviewer believed there is a missed opportunity here. MD simulation already showed for USW that increased temperature and lateral strain increases the joint strength. The reviewer asked where the process development is targeting this. Characterization of the Mg-Zn eutectic is paramount; however, the reviewer would challenge the Interface by Design initiative to define the optimum Mg-Zn eutectic thickness in order to optimize the welding parameters accordingly.

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

Reviewer 1:

The reviewer noted that this project is halfway through the performance period. A great deal of progress has been made to define the load bearing capacity, clamping forces, presence and thickness of intermetallic compound layers, presence of coating material, joint strength, fracture locations, material properties at the weld interface, and barriers to corrosion. The reviewer said that the positive results of this research have contributed significantly to successfully meeting the milestones and performance.

Reviewer 2:

This reviewer commented that the accomplishments are laudable. Clear progress on fabricating, characterizing, and testing joints. However, it seems the corrosion work can go deeper—24 hours of exposure seem short, and should be justified. The reviewer said it would also be useful to mechanically test the joints after corrosion exposure.

Reviewer 3:

The reviewer pointed out that no overall plan was presented to show the deliverables/timing. This project has successfully completed the 2019 deliverable included in Slide 4.

Reviewer 4:

This reviewer said it is unclear why USW creates intermetallics in the joints involving Zn-coated DP590, because the process temperature is (presumably) low. The reviewer suggested instrumenting the interface with a thermocouple to understand what drives the formation of Mg-Zn. T-peel tests are known to be unreliable, not just due to asymmetry but also because they induce combined loading. Material properties for tensile or shear cannot be deduced from T-peel tests. The reviewer remarked there are shear jigs that allow for localized shear testing with minimal combined loading. The corrosion study points to significant corrosion products. The reviewer asked how this issue is going to be addressed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer indicated that collaboration for this project is between two DOE National Laboratories with several researchers from each, with tasks equally divided between both National Laboratories for the two technologies being investigated. Modeling and experimentation appear to be well coordinated at and between both labs. At this level of research, involvement from a university could possibly improve the research findings.

Reviewer 2:

The reviewer remarked that coordination across existing partners seems very good and effective. It would also be good if further industry participation could be developed.

Reviewer 3:
The reviewer stated that collaboration between PNNL and ORNL is clear.

Reviewer 4:
This reviewer asked how the team is going to use the USW Mg/Fe and Mg/Zn-coated steel interface to investigate the FSW Mg/Zn-coated steel interface. It seemed to the reviewer that USW offers an opportunity to uniquely define the Mg/Fe interface and Mg-Zn eutectic properties which can then be applied to the FSW joint in order to differentiate the hook effect from the Mg/Fe or Mg-Zn eutectic.

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

Reviewer 1:
The reviewer remarked that there is a good plan going forward. Characterization of mechanical peel mode is particularly appropriate.

Reviewer 2:
The reviewer commented that proposed future work involves completing the current tasks to produce results that will address the barriers discussed, which is a logical sequence. No decision points are given. There were no alternate development pathways discussed; however, the approach for obtaining the necessary data is straight forward so any risks are minimal.

Reviewer 3:
This reviewer described the tasks outlined as good. The reviewer would modify the USW Mg-Fe interface investigation to include a comparison of the Mg-Fe interfaces of USW versus FSW. It is necessary to understand (Slide 8) why there was a significant increase of in Mg-Zn eutectic at weld interface compared to outside of the hook region.

Reviewer 4:
It was unclear to this reviewer that a thorough understanding of process-property relationships can be achieved without a formal matrix/design of experiments study. As noted, further instrumentation may be needed to understand process temperatures, as well as improved mechanical tests to isolate shear and tensile modes. Cross-tensile (x-shaped joints) is a good test for isolating normal stresses.

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

Reviewer 1:
The reviewer remarked that this project targets strategic lightweight materials, and addresses the strategic focus area of dissimilar material joining

Reviewer 2:
The reviewer asserted that the research results presented are directly relevant to addressing the barriers for joining and maximizing joint performance for dissimilar metals that were established by the DOE VTO. In addition, the experimental results will support modeling efforts of the Interface by Design team to address future DOE needs.

Reviewer 3:
This reviewer stated that joining Mg and high-strength steel is essential to next-gen multi-material vehicles.

Reviewer 4:
The reviewer indicated that this is an important topic relevant to lightweighting objectives.

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

Reviewer 1:

The reviewer noted that this project is funded at $1.7 million for 3 years for two DOE labs, which is an average of $283,000 per year per lab. Given the number of researchers at each lab conducting the research, the funding, personnel, and facilities are sufficient to complete the project as designed.

Reviewer 2:

This reviewer commented that the budget seems reasonable for the program goals and timeline.

Reviewer 3:

The reviewer offered no concerns because the resources are sufficient for conducting the tasks proposed.

Reviewer 4:

Without an overall plan with activities, deliverables, and timing, this reviewer cannot comment on whether or not there are sufficient resources available or not. The reviewer would not include corrosion in this project and focus the resources on developing the process parameter/interface strength mapping. The reviewer believed corrosion should be a separate initiative and that inclusion in this project just diverts attention from the critical deliverable.

Presentation Number: mat139
Presentation Title: Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium
Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

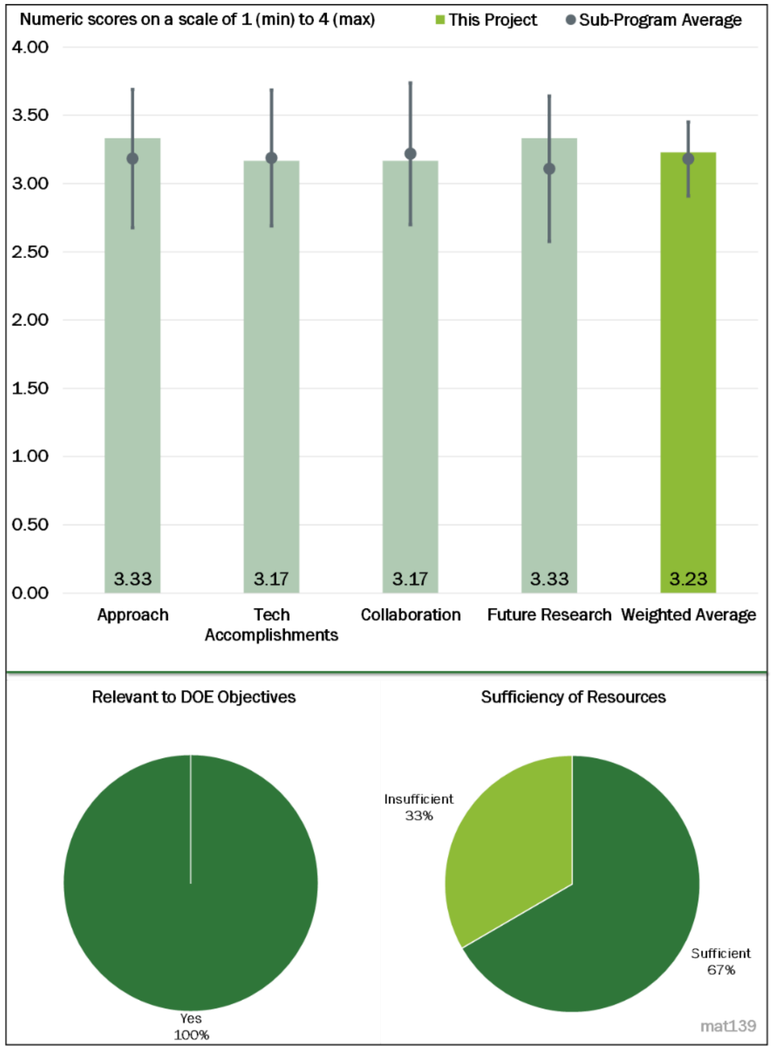

Figure 6-15 – Presentation Number: mat139 Presentation Title: Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

Presenter
Scott Whalen, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer asserted that joining Mg and CFRP is essential to aggressive vehicle mass reduction. This program has timely and important innovations to develop new joining strategies. Great plan.

Reviewer 2:
The reviewer noted that this is a short-term, two-year project to develop new techniques and improve performance over existing methods of joining dissimilar materials. If successful, the two techniques of friction stir interlocking and bolting with self-piercing riveting will allow two vastly dissimilar materials—Mg and a CFRP—to be joined and used as lightweight materials in components of automotive structures; a major goal in the VTO lightweight materials program. The reviewer said these techniques may also allow for high-volume manufacturing of automobile assemblies with minimal corrosive effects for the resultant assembly.

Reviewer 3:
The reviewer noted that a broad range of processes is considered, with appropriate downselect giving unique challenges for each of the processes included. The corrosion testing is highlighting the general corrosion of Mg. However, typically Mg would not be used in the bare state—either the Mg would be coated or the entire joint E-coated. The reviewer said corrosion testing should perhaps focus on this or in some way isolate the behavior of the joint.

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

Reviewer 1:

This reviewer said that for a short, two-year project, the technical accomplishments and progress have been significant, although not all the requirements have been met based on test data. This is an early-stage research project and some amount of risk is involved in meeting stated goals. The project is executing as planned and progress is excellent for the effort expended.

Reviewer 2:

The reviewer stated that there is very good technical progress being made. This reviewer suggested that there should be additional emphasis on getting data in front of potential adopters in a more aggressive way and benchmarking this in such a way that designers can make use of the data. Also, be mindful to use International System of Units (SI) units. There were mixed pounds and Newton units.

Reviewer 3:

This reviewer noted that no data or discussion of tool geometry or process window development were presented, which was a Task 1 deliverable per Slide 4. The Task 2 accomplishments seem to be well on their way and making progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said that for early stage research and a short performance period, the collaboration between the two DOE National Laboratories and a materials supplier has been outstanding in obtaining results (good or bad) that characterize the failure mechanisms between the two joining techniques. The tasks appear appropriately divided between the two National Laboratories with each lab performing well within its technical competency and with regular exchange of information between the two labs.

Reviewer 2:

The reviewer stated that coordination across the existing team looks very good. It would be better with a larger number of industry participants.

Reviewer 3:

This reviewer said it is not clear how each of the teams are learning from one another and how those learnings are being applied.

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

Reviewer 1:

The reviewer stated that the proposed future research is for completing the project within the next year. Although no decision points were discussed, the efforts to improve friction stir interlocking through tooling and process optimization, to determine effects of and mitigate corrosion, and to evaluate residual stresses and identify failure mechanisms will result in the project meeting all goals and objectives.

Reviewer 2:

The reviewer described the plan as excellent. More coupling with solid mechanics modeling to develop formal interface toughness would be welcome.

Reviewer 3:
This reviewer asked why bolting is not included in the future work. If coating is to be included as part of the corrosion work then there should be some fundamental measurements of corrosion potential between couples, and not just apply a coating and look at the ASTM B117 test results. However, this may have impact upon available budget/resources.

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

Reviewer 1:
This reviewer noted that the project evaluates joining techniques and effects on materials used for construction of lightweight components used in automotive structures. One of DOE VTO's primary objectives is to reduce the weight of vehicles using lightweight materials for construction of parts and assemblies; therefore, this project directly supports this DOE objective.

Reviewer 2:
This reviewer stated that there is a clear need to join these ultralight materials to satisfy DOE objectives.

Reviewer 3:
The reviewer noted that this project targets strategic lightweight materials, and addresses the strategic focus area of dissimilar material joining and corrosion.

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

Reviewer 1:
The reviewer commented that the budget is in line with tasks.

Reviewer 2:
This reviewer noted that the project is funded at $1.8 million for 2 years for two performers or about $450,000 per performer per year. The reviewer said this is somewhat high for typical research projects; however, the performance period is only two years, and this is early-stage research, so more resources (personnel and facilities) are required to meet the timeframe, which can result in a higher annual budget.

Reviewer 3:
Without being presented an overall plan with activities, deliverables, and timing, this reviewer cannot comment on whether or not there are sufficient resources available.

Presentation Number: mat142
Presentation Title: Metal-Matrix Composite Brakes Using Titanium Diboride
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

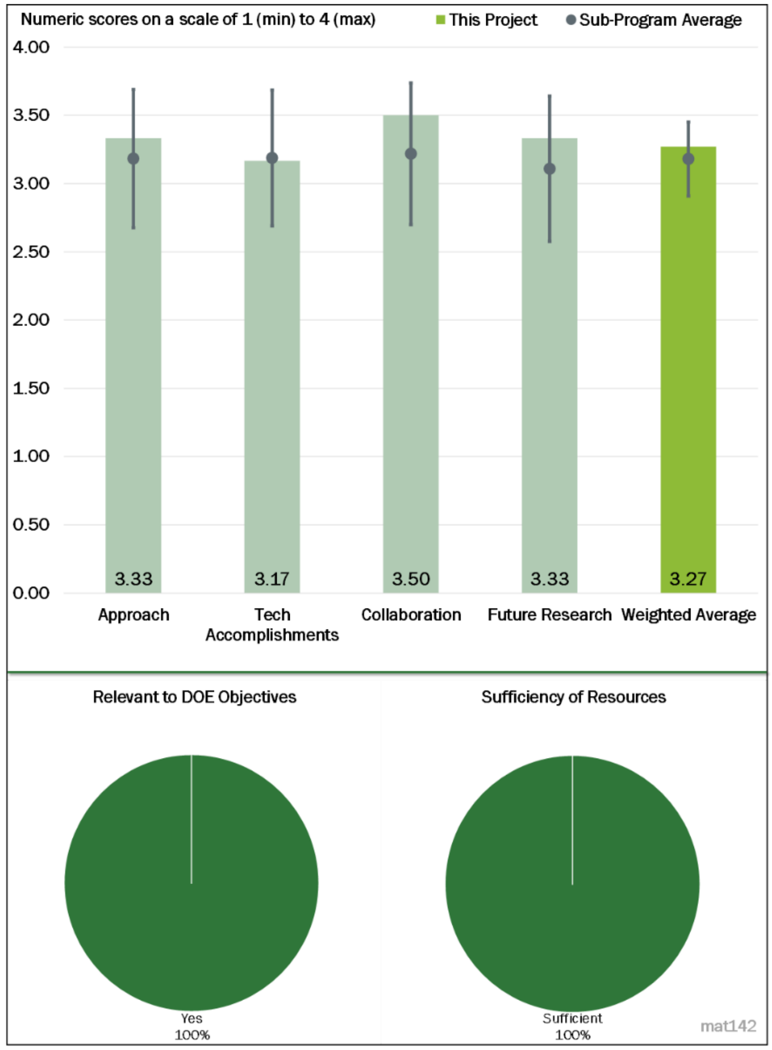

Figure 6-16 – Presentation Number: mat142 Presentation Title: Metal-Matrix Composite Brakes Using Titanium Diboride
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer said the project addresses the barriers in cost of feedstock and production. The tasks are well defined to address the barriers.

Reviewer 2:

The reviewer stated the concept is novel and it would be interesting to see the actual friction pair testing with the fabricated Al-titanium diboride (TiB_2) metal matrix composite rotor disks.

Reviewer 3:

The reviewer remarked that the approach was good, but with stir casting there is a certain amount of oxides that are generated. It would also be good to examine the grain size as TiB_2 is traditionally used as a grain refiner.

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

Reviewer 1:

The reviewer commented that the team has done a good job characterizing the TiB_2 3-micron particle distribution. Because there is a wear issue involved it would also be good to look at hypereutectic alloys such as A390, etc. This reviewer would like to have more discussion on the high temperature behavior.

Reviewer 2:

The reviewer stated that this project has delivered performance indicators.

Reviewer 3:
This reviewer said it is encouraging to see that rotors could be successfully made from the stir casting. But, considering the fact that there are many variables (powder particle size distribution, volumetric percent of composites, stirring condition), it would have been ideal to share the design of experiments strategy.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer said the team did a good job with communication and collaboration with all parties involved.

Reviewer 2:
The reviewer noted that collaboration with the material supplier was detailed.

Reviewer 3:
The reviewer indicated that collaboration between PNNL and Acronic seems very close and supplementary to each other.

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

Reviewer 1:
The reviewer commented that the next steps to complete the project are defined and logical to address barriers.

Reviewer 2:
This reviewer indicated that the friction pair testing results of the actual rotor discs will be very interesting. It would be ideal if the team can benchmark the result of friction testing with the conventional rotor discs.

Reviewer 3:
This reviewer suggested that it would also be good to examine the A356 silicon carbide centrifugal cast brake rotor from a U.S. Automotive Materials Partnership (USAMP)/United States Council for Automotive Research program.

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

Reviewer 1:
This reviewer said the scope of this project is highly relevant to DOE mission space.

Reviewer 2:
The reviewer stated that unsprung mass reduction has a large impact on the lightweight performance of the vehicle.

Reviewer 3:
This reviewer stated that the project is relevant respective of lightweighting, life cycle analysis, and lower rotational inertia energy losses for battery electric vehicles.

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

Reviewer 1:
The reviewer observed sufficient project resources to complete all tasks.

Reviewer 2:

This reviewer commented that it was a good split with $300,000 being from DOE and $360,000 from Arconic.

Reviewer 3:

The reviewer noted that the resources seem appropriate to achieve proposed research tasks. However, it would have been better to add a bit more fundamental level smaller lab scale testing to optimize variables associated with processing/materials, such as particle size distribution, stirring condition, volume percent of particles, etc., before PNNL lab scale stir casting. Also, coupon sample for testing of "simpler" friction testing can also be considered with the increased funding level in the future.

Presentation Number: mat143 Presentation Title: Mitigating Corrosion in Magnesium Sheet in Conjunction with a Sheet-Joining Method that Satisfies Structural Requirements within Subassemblies Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

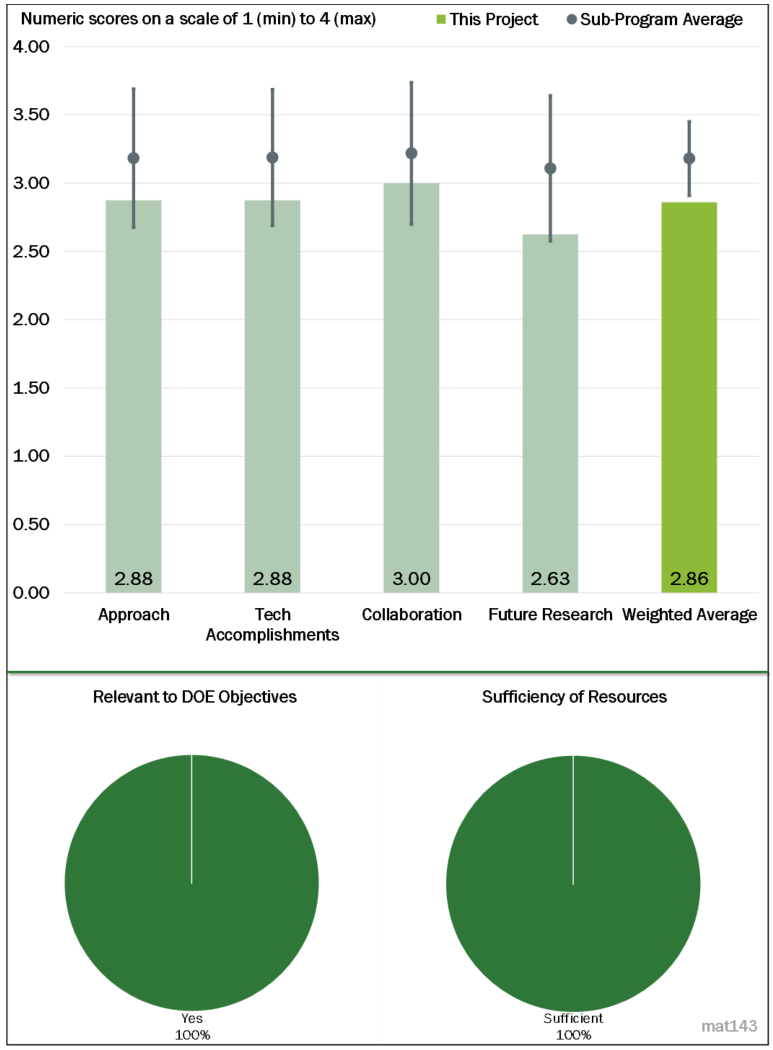

Figure 6-17 – Presentation Number: mat143 Presentation Title: Mitigating Corrosion in Magnesium Sheet in Conjunction with a Sheet-Joining Method that Satisfies Structural Requirements within Subassemblies Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

Presenter

Saumyadeep Jana, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer said that the approach articulated appears logical.

Reviewer 2:

The reviewer stated that the corrosion of coated and/or joined Mg will be important for use of the alloy. However, the gravimetric approach employed does not seem to control well for loss of material due to fragmentation. Details of the alloy and resulting electrochemistry of the bonding material (Al, steel, rivet material, clinch lock) were absent, and seem key to relevance of the work.

Reviewer 3:

The reviewer commented that the project principal should ensure a full understanding of the technology used including the type of coating. When characterizing the performance of coatings in salt spray test, this is typically done against damages (e.g., scratches and stone chippings). A vision needs to be formed to technically link both assembly and coating of Mg-sheet components.

Reviewer 4:

This reviewer said the project approach does not appear to address two of the three technology gaps stated on the “Overview” slide. Specifically, it is not clear that the process is addressing a “lack of corrosion resistant magnesium (Mg) alloys,” and the presentation does not indicate the project is addressing “lack of cost-effective, durable protective coating” by developing any new coating technology, but instead, the corrosion evaluation seems to focus on currently commercially available Mg pretreat and conventional e-coating technologies.

Additionally, dissimilar metal joining alloys (steel and Al) are not identified. The reviewer said joining of a high-copper containing Al (such as 6013 or most 7xxx alloys) will show substantially higher galvanic corrosion with Mg than will lower-copper containing alloys such as 6016 or most 5xxx alloys. It was unclear to this reviewer whether these dissimilar metals will be bare or will be coated.

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

Reviewer 1:
No delays seemed to be apparent from this reviewer's perspective.

Reviewer 2:
This reviewer explained that the technical accomplishment is reasonable given the delay in receiving the samples.

Reviewer 3:
This reviewer stated that the project seems behind schedule. The technical accomplishments to date seem limited to only the bare materials. The project is listed at 45% complete, but that seems to be counting only the number of milestones, not the technical difficulty of the milestones. As the time allotted is 84% complete, and that none of the joining milestones are complete, this seems a significant concern.

Reviewer 4:
Although the program is admittedly behind schedule due to delayed start at M3, it still seemed to this reviewer that most of the corrosion work thus far is very rudimentary and has not really started to address the major challenge of corrosion of joined assemblies, either similar (all Mg) or dissimilar (Al and steel alloys not defined). Instead, the work reported only addresses corrosion of Mg alloy coupons that have not been joined to other Mg coupons or dissimilar materials, and at that, there is nothing in the report indicating the coatings are anything new or innovative. Additionally, remarked the reviewer, there is no stated solution to the issue of being unable to weld through the pretreated Mg.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer stated that collaboration appears reasonable given the time elapsed on the project.

Reviewer 2:
The reviewer noted that although Henkel is identified as a third partner, providing coating services to Magna, this is essentially a two-partner project, so coordination should not be a major challenge. The responsibilities appear to be reasonably defined in the Task/Milestone Summary.

Reviewer 3:
The reviewer noted that delays in proving material were identified in the presentation. This delay seemed to affect all aspects of the program and coordination of work.

Reviewer 4:
The reviewer said to please ensure important information is shared between project partners.

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

Reviewer 1:
The reviewer suggested that the design of the test matrix should be discussed with respect to potential applications. This will give a better guidance as to the relevance of certain samples.

Reviewer 2:
The reviewer observed that the proposed future work seems to be purely in line with the original program direction without any proposed changes in direction or discussion of alternative paths as a result of the fact that the coating had to be removed in order to weld the samples.

Reviewer 3:
This reviewer noted that the future research seems to largely be composed of completion of work. No clear decision points were identified that would impact the future research (i.e., if the joint material is already badly corroding at 200 hours, is it necessary to complete the full 1,500 hours).

Reviewer 4:
This reviewer said it was not clear how the proposed future work was aligned in addressing the uncertainties listed on Slide 16. Furthermore, the reviewer asked what additional variables are introduced by removing the pre-treatment layer prior to use of Arplas. It will also be great if in a future presentation, the selection of the joining techniques for the project is described in more detail. The reviewer asked if the selection is based on industry best practices for joining Mg.

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

Reviewer 1:
This reviewer said the project does support the overall DOE objectives by addressing two of the major challenges (joining and corrosion) with using Mg (the lightest metal) by itself and joined to other metals.

Reviewer 2:
The reviewer stated that joining dissimilar materials will be a critical element of multi-material vehicles. Mg has a high potential to lightweight vehicles that has yet to be realized commercially.

Reviewer 3:
This reviewer said that joining is an important hurdle that needs to be addressed in Mg research.

Reviewer 4:
This reviewer said it does support the overall DOE objectives, as the project is focusing on corrosion assessment. The research is not necessarily focused on corrosion mitigation. It appears to be evaluation of two different pre-treatments from Henkel, the evaluation of joining techniques, and corrosion performance.

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

Reviewer 1:
This reviewer said the project appears to have reasonable deployment of resources to support project objectives.

Reviewer 2:
The reviewer stated that there are no obvious lacking or excessive resources identified, beyond the supply of the material in the first place.

Reviewer 3:
This reviewer said there was no indication of insufficient resources.

Reviewer 4:
This reviewer noted that the project essentially includes three partners, one to establish joint configurations, one to provide pretreatment/coatings, and one to perform the corrosion evaluation. This should be sufficient for the limited scope of the project. However, it does appear that more innovative thought and attention to detail will be required to ultimately produce the desired outcome for this project. Additionally, timing and budget should be sufficient.

Presentation Number: mat144
Presentation Title: Reducing Mass of Steel Auto Bodies Using Thin, Advanced High-Strength Steel with Carbon-Fiber Reinforced Epoxy Coating
Principal Investigator: Gabriel Ilevbare and Dave Warren (Oak Ridge National Laboratory)

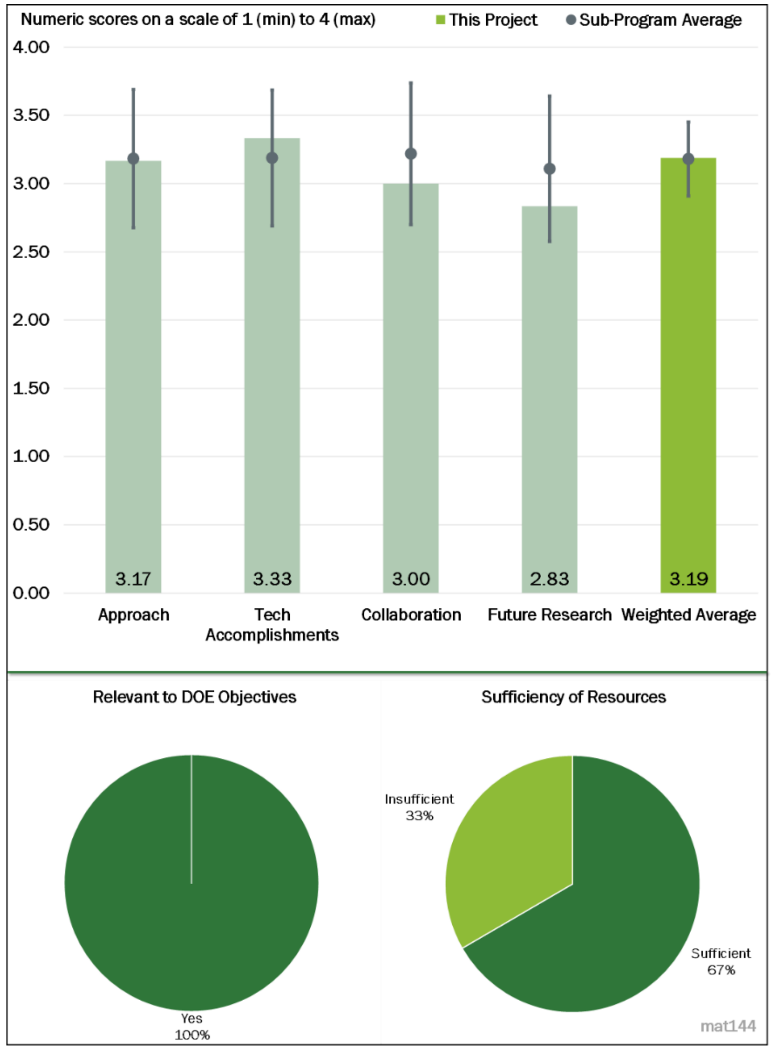

Figure 6-18 – Presentation Number: mat144 Presentation Title: Reducing Mass of Steel Auto Bodies Using Thin, Advanced High-Strength Steel with Carbon-Fiber Reinforced Epoxy Coating Principal Investigator: Gabriel Ilevbare and Dave Warren (Oak Ridge National Laboratory)

Presenter
Dave Warren and Gabriel Ilevbare, Oak Ridge National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
An excellent approach was observed by this reviewer, who suggested extending the testing plan to include noise transmission and damping for the outer door panels. Also, there should be more details on how the cost modeling and economic evaluations will be performed.

Reviewer 2:
The reviewer remarked that the approach was good, but will have to consider the final product. As this was a method to develop the CF epoxy that would be added onto the door after stamping, which would require an additional station/operation in the door assembly area—and extra cost to the final product.

Reviewer 3:
The reviewer commented that the project represents an innovative approach to a multi-materials solution for use of high specific property carbon composite and steel to achieve impressive lightweighting while overcoming the barriers of composite materials in automotive applications. Total project funding is modest while the work appears comprehensive and adequate to (at a minimum) determine feasibility and provide significant accelerated lifetime durability data to encourage follow-on work in this application. This reviewer noted four elements of minimal concern related to approach:

First, typically, when looking at feasibility of a replacement material, a high-level economic analysis (the “business case”) is presented. This particular effort would appear to benefit from this at the front end, both to motivate the work as well as to optimize the weight savings at the minimum cost per incremental kg of weight saved. It would appear straightforward and this project would benefit from this being front and center at the outset.

Second, it would seem critical to ensure uniform dispensing of the fiber/epoxy paste such that thickness, fiber distribution (percent weight and orientation) is properly accomplished. This reviewer would have expected more effort applied to the assurance that this can be accomplished or a description of the variance allowable based on some of the testing (tensile or flexural) being performed. Indeed, the PI presented test data and showed error bars in trend lines and proceeded to draw “questionable” trend lines (the reviewer asked if they were calculated by regression). It would have been useful for the variance to be correlated with either report thickness variance in the composite substrate or with fiber orientation that might become preferential as a result of the manner of application (spray, trowel, shovel, etc.).

Third, finally, this project has described an extensive set of environmental testing of this combination of steel and CF. The limited amount of corrosion seen in the steel actually surprised this reviewer as there is little noted about insulation between the carbon and the steel where galvanic corrosion effects may be of concern. This reviewer asked if the PI believes there may be long–term effects where a galvanic corrosion loop might appear with time/use, and if there would be benefits/costs/issues with provision of a very thin dielectric barrier between the two substrates.

Fourth, final comment related to any thermal distortion one might expect. This reviewer would have been interested to see results of out-of-plane distortion that occurs when an unrestrained flat plate of this material (of arbitrary size) is subjected to a range of temperatures from about -40°C to 80°C. The differential CTE between the substrates would be expected to yield some level of curvature. Clearly, this can be calculated easily as well. In a restrained plate one would expect this to yield modest to significant thermally induced stresses. The reviewer said some validation of cyclic thermal loading without disbonds or other signs of failure in the substrate adhesion would be welcomed.

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

Reviewer 1:

This reviewer said the project is making excellent progress. The tasks appear to be at or ahead of schedule to meet the completion date. This reviewer wanted to see more details on the cost modeling and economic analysis. The corrosion results are promising that this could be included into production systems. Other manufacturing testing such as handling, smearing, or e-coat wash off would be valuable additions to the testing plan. The effect of the reinforcement on the final Class “A” painted surface would need to be investigated. “Read through” might show through the painted surface. Also, noise, vibration, and harshness (NVH) testing including sound transmission loss and damping factor would be valuable design information. The reviewer said project funding is far below the required efforts to address the barrier of low-cost, high volume manufacturing.

Reviewer 2:

The reviewer stated that the technical accomplishments related to the load capability, corrosion resistance, and failure modes demonstrate a significant wealth of validation given the funds expended. There is a note in the PI's presentation regarding “CTE evaluation in each of three directions. (2018)”. This reviewer has not been able to see the results of that work, if it has been accomplished. The wealth of data representing accelerated corrosion testing is well worth the investment in this application to date.

Reviewer 3:

This reviewer said the team has done a good job on characterizing the corrosion behavior, but the team had added a trend line to the humidity test that show decreasing properties with longer exposure, but the data indicates that all conditions are about the same within the error of margin that you could measure.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said the project is a solid collaboration between industry and National Laboratory partners. While the PI has spelled out the responsibilities of each partner, there is overlap described (e.g., “corrosion performance”); it is not entirely clear where the responsivity for this lies related to this year's work. Small point, but the responsibilities are redundant; this reviewer wondered about the distinction between ArcelorMittal and INL’s work.

Reviewer 2:

The reviewer stated that the partners have clear roles and responsibilities. There is little information about the interactions or “cross-talk.” There are likely regular interactions and scheduled review meetings. The reviewer said it would be beneficial to share these project management details.

Reviewer 3:

The reviewer observed good communication with the different labs involved; however, it would be nice to reach out to a door assembly facility to check on the practicality of an epoxy that adds to the cost ($4.50 per pound for recycled CF and $8 to $9 per pound for virgin CF).

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 the ambiguity within the presentation (Slide 22) to discuss “future work” when describing past dates leaves this reviewer confused about what is to come. The reviewer requested that the PI present “Future work” as that work that is “yet to be accomplished” rather than what appears to be a schedule of work both past, present, and future. It would have been informative for the PI to provide more detail regarding the specific door component to be interrogated in the design effort.

Reviewer 2:

This reviewer said that there is little detail on the proposed future research. The item “Cost and Mass Study” needs to be better explained. Also, the proposed future work does not include manufacturing evaluations, such as wash off or paint system interactions or NVH testing. These are important (apparently overlooked) aspects of the technology.

Reviewer 3:

This reviewer recommended that instead of just test coupons it would be great to see the actual door values on stiffness, etc.

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

Reviewer 1:

The reviewer stated yes, this project is absolutely relevant and supportive to DOE objectives. The effort represents an innovative approach and thoughtful use of lightweighting materials in a strategic manner to use low-cost forms of carbon hybridized with steel to overcome many traditional barriers in composite molding for external components, while achieving a significant reduction in component mass. The reviewer said that while no specific costs have yet been postulated, it would be expected that incremental cost per kg of weight removed from the vehicle is likely to meet DOE objectives for lightweighting.

Reviewer 2:

This reviewer remarked that automotive doors are usually the lowest cost to lightweight the vehicle as compared to other areas (chassis, body in white, etc.).

Reviewer 3:

The reviewer indicated that this technology could reduce the mass of vehicles by a few kilograms. This would be a small improvement to fuel efficiency. The project investment is well aligned with the expected/anticipated benefits.

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

Reviewer 1:

This reviewer commented that the project is making good use of the resources given to the PI's.

Reviewer 2:

The reviewer asserted that this is an innovative approach that is modestly funded with the intention of providing a full-scale component. The research plan and activities are commensurate with the funds reported by the PI. If the economics align well (as might be expected) it would likely take more dollars to commercialize, but this reviewer could imagine the value to be such that the investment would flow privately. More funding would offer the opportunity to complete additional full-scale testing and other operational and environmental evaluations. However, bottom line, resources are well aligned with the stated milestones.

Reviewer 3:

This reviewer noted that costs probably do not allow for a manufacturing and NVH investigations. It would be a stronger project if more manufacturing issues could be addressed. The testing plan should be extended and the cost modeling should be stronger or certainly described more clearly. Also, the "Resources" Slide is confusing. The reviewer asked what was spent in FY 2017 before the project started (if it was really $300,000 before the project started), what was spent in FY 2018 and FY 2019, and planned for FY 2020. The reviewer said Slide 2 does not make sense.

Presentation Number: mat146
Presentation Title: Ultra-Lightweight, Ductile Carbon Fiber Reinforced Composites
Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory)

Presenter

Vlastimil Kunc, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

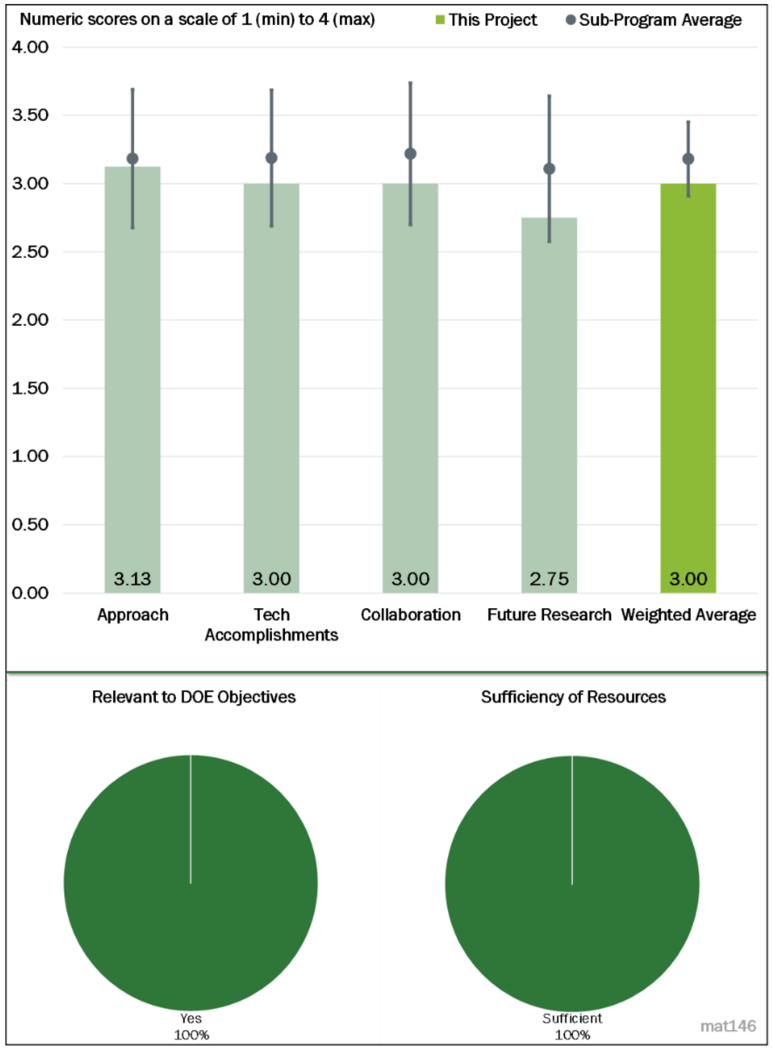

Figure 6-19 – Presentation Number: mat146 Presentation Title: Ultra-Lightweight, Ductile Carbon Fiber Reinforced Composites
Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer described the approach of creating three-dimensional (3D) printed CF composites for lower density and high damping as very interesting. The results are very promising.

Reviewer 2:

The reviewer observed really interesting, fundamental materials work. The presenter and the presentation materials did not outline a specific and defined approach, but stepped the reviewer through accomplishments, material/mechanical behavior, and some presentation of material characteristics. The takeaway is that the micro lattice provides an opportunity to build much lower density CF-based materials while simultaneously improving apparent ductility in what are traditionally brittle materials. The specified work to fabricate and deliver a scaled-up version of an UV-based (curing) 3D printing system for the microlattice structure is clearly an important next step. The reviewer remarked it would have been helpful were the approach to contain a specific targeted application (whether to provide low-weight damping in an NVH application, or some other apparent vehicle application).

Reviewer 3:

The reviewer stated that this is an interesting project and the presenter did a good job providing project overview highlights with little advanced notice. It is unclear exactly how this new building-block structure will be used. If this reviewer understands correctly, the intent here is to print a microstructure that itself can be used as a material building block. The reviewer reported that this microstructure consists of a carbon-filled, UV-curable resin, which together exhibits some structural properties; as well as an unfilled, soft, UV-curable resin. It appears that the theoretical work points to an ideal ratio of the soft to the carbon-filled and this combination has been printed in a lattice or unit-cell-type microstructure, where multiple lattice geometries were explored and one selected to yield the desired combination of properties.

The reviewer asked how will this printed structure—we can call it a “meso-structure”—be used, and is this printed meso-structure to be treated as a material itself. If so, the reviewer asked what candidate parts, macro-structures, or applications are being considered, what would a part fabricated from this meso-structure material look like, and how would such a part be fabricated. Clarification of this point would help clarify what questions should be asked of the present approach for the intended application space. Even if consideration of specific candidate applications is premature, the reviewer asked how would a flat plate with a centrally-located, through-thickness circular hole from this material be fabricated.

Reviewer 4:

The reviewer noted that the target is: “Hybrid hierarchical CF reinforced materials that are ultralight, strong and tough for 3D printing.” However, much of the attention is focused on the structural design. This reviewer does not see how these align to produce reinforced materials for 3D printing.

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

Reviewer 1:

This reviewer said the project shows good progress in creating a lightweight, high stiffness lattice structure.

Reviewer 2:

The reviewer observed that the project is making good progress, both experimentally and with modeling. Using numerical simulation may prove useful in evaluating the properties of the meso-structure with both stiff and soft material. In other words, the project is trying to take advantage of both structural and material (or intrinsic) properties and create a new “meta-material” or meso-structure with engineered properties. While analytical models exist for exploring the effects of structural geometry and of material properties individually, it is unclear (and unlikely) whether analytical models exist for exploring the combination of structural and material properties together. Addressing the combination of structural and material properties is where simulation may best serve the program.

Reviewer 3:

The reviewer noted that for the brief period of performance that has been reported, the PI and team have accomplished much in terms of micro lattice structures on a limited scale. The team has tested various loading levels of CF as weight percent, and that is an important limitation of the UV process technology. This reviewer must comment, however, on the modest stiffness performance obtained from these “CF” composite materials. The PI presented a relationship between CF load (percent weight fraction) and Elastic Modulus of the printed material. At loading levels of 35% weight fraction CF (a target not yet achieved) the resulting material modulus is show to be approximately 6 gigapascal (GPa). Carbon fiber composites (even quasi-isotropic constructions) exceed 56 GPa, or more than 10 times at typical fiber weight fractions of about 60%. The performance (from a purely structural stiffness vantage point) of these printed materials is somewhat underwhelming. This reviewer wanted to see more revelation of the applications that will most benefit from this technology (where the damping performance and material stiffness marry to create enabling applications).

The progress on a larger scale printing apparatus looks very promising and this reviewer emphasized looking forward to seeing visible quantities of the micro lattice fabricated. The reviewer stated it would be helpful to hear projections regarding the deposition rates of material and how the team believes this can scale.

Reviewer 4:

The reviewer commented that the technical accomplishments reported are a first step towards the goal of developing tough, strong materials for 3D printing. The focus on lattice structures is interesting given the best possible tolerance is 200 microns. If the resolution of the UV printing system is 200 microns, the process capacity index (Cpk) of the process to produce any part will be larger than 200 microns. Most automotive parts have tolerances of approximately 100 microns. This reviewer struggled to see how this process can achieve any typical automotive part dimensional requirements. The new frame and machine under construction does not appear to be sufficiently stiff to study or control dimensions to the precision typically required. The reviewer inquired about the following: whether the lattice structure typical dimension is 2 mm to 5 mm; the parts targeting by the project team; and how working on lattice structures advances the goal of producing hybrid hierarchical CF reinforced materials that are ultralight, strong, and tough for 3D printing. It appeared to this reviewer that the only 3D printing technology the team is investigating is UV cure polymers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer stated that there is good collaboration with the university in this research project.

Reviewer 2:
This reviewer said the collaboration between Virginia Tech and ORNL is appropriate for this stage of the project. This is a very preliminary research-type project that requires expertise in additive manufacturing. Hence, university researchers and ORNL engineers are a good fit. The partners appear well coordinated.

Reviewer 3:
The reviewer noted that the team is of modest size and the interaction related to the design and fabrication of the larger scale printing system is on track and nearly complete. That bodes well and exemplifies the coordination that is occurring between the project groups. Good effort.

Reviewer 4:
This reviewer said there is no clarity on the roles and responsibilities of the partners. This presentation does not list any meeting cadence to indicate any coordination between partners. The work performed at ORNL versus what is performed at Virginia Tech is unclear.

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 interrogation of the materials being developed and tailoring of material systems look like an adequate path forward. Little is discussed related to the value of the materials and the cost to produce. It is difficult without specific applications in the vehicle space to fully comment on the progress toward specific targets. The overall stated objective does not contain specific metrics, so providing additional comment on the proposed activities and the realization of those metrics is difficult to evaluate as well.

Reviewer 2:
This reviewer said the proposed future work has several significant challenges. It is not clear how they will be solved as the needed work needs some new development and it is not directly resulting from the past work.

Reviewer 3:
As indicated, the reviewer anticipated that scale-up will be the major challenge. The reviewer would like to see more evidence or thoughts regarding scale-up to printing volumes and geometries relevant to actual structures. This reviewer did not see how this would be used to print an automotive component.

Reviewer 4:
The reviewer noted that the proposed future work is only marginally tied to the project objective of developing hybrid hierarchical CF reinforced materials that are ultralight, strong, and tough for 3D printing. Demonstrating a composite with tailored energy absorption, high strain recovery, and fabricating lattice materials are only tenuously tied to the material development goal. The reviewer had hoped to see material

development, material robustness, and 3D printing processing studies on a number of candidate material systems in the future work.

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

Reviewer 1:

The reviewer stated that the project is relevant to explore new CF designs for ultra-low density and high energy absorption.

Reviewer 2:

This reviewer indicated that the project is focused on an interesting issue in vehicle dynamics, namely provision for a unique combination of structural stiffness and damping not available through material or geometric selection alone.

Reviewer 3:

Although the project objective supports the DOE goal for lightwieght materials, this reviewer pointed out that the project's current trajectory is not aimed at achieving the project objective.

Reviewer 4:

This reviewer remarked that the direct line drawn between the current project objectives and research and DOE and VTO objectives is not entirely clear. However, the work of innovative materials research at a fundamental level is vitally important to uncover opportunities not yet understood or imagined. This reviewer believes the modest cost of the innovative work to create materials with intricate, engineered microstructures, will find a home somewhere on future systems. The reviewer felt that there is a fundamental disconnect between materials with 6 GPa of stiffness and a comparison with unidirectional (UD) carbon composites that exceed 180 GPa. To compete on a specific stiffness basis the micro-lattice must be almost two orders of magnitude less dense. This reviewer encouraged the PI to build some specific performance metrics to help provide useful comparisons and help industry evaluate applications that will benefit from the unique performance of the resulting materials.

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 sufficient resources to complete the project.

Reviewer 2:

This reviewer stated that the budget is as would be expected for this scale project and participants.

Reviewer 3:

This reviewer said that a lack of performance metrics makes evaluating the technology gap remaining and the resources necessary to bridge that gap difficult to assess. Based on the work proposed for the next budget period, it appears the resources are available to address the challenges. One obvious concern is the ability to cure with UV light more densely packed CF materials. The questions will remain how that limitation will affect the technology and viability to scale or find useful applications.

Reviewer 4:

The reviewer stated that the overall resources of $500,000 should be sufficient to develop a couple of candidate materials. This reviewer is concerned that $460,000 of the $500,000 has already been expended. Also, the start date on Slide 2, of October 2019, cannot be accurate. This reviewer is confused on how $460,000 of $500,000 could have been spent and 40% project completed before the project has started. These dates, percent completion, and funding levels appear inconsistent.

Presentation Number: mat147
Presentation Title: Continuous Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression-Forming Process
Principal Investigator: Philip Taynton (Mallinda, LLC)

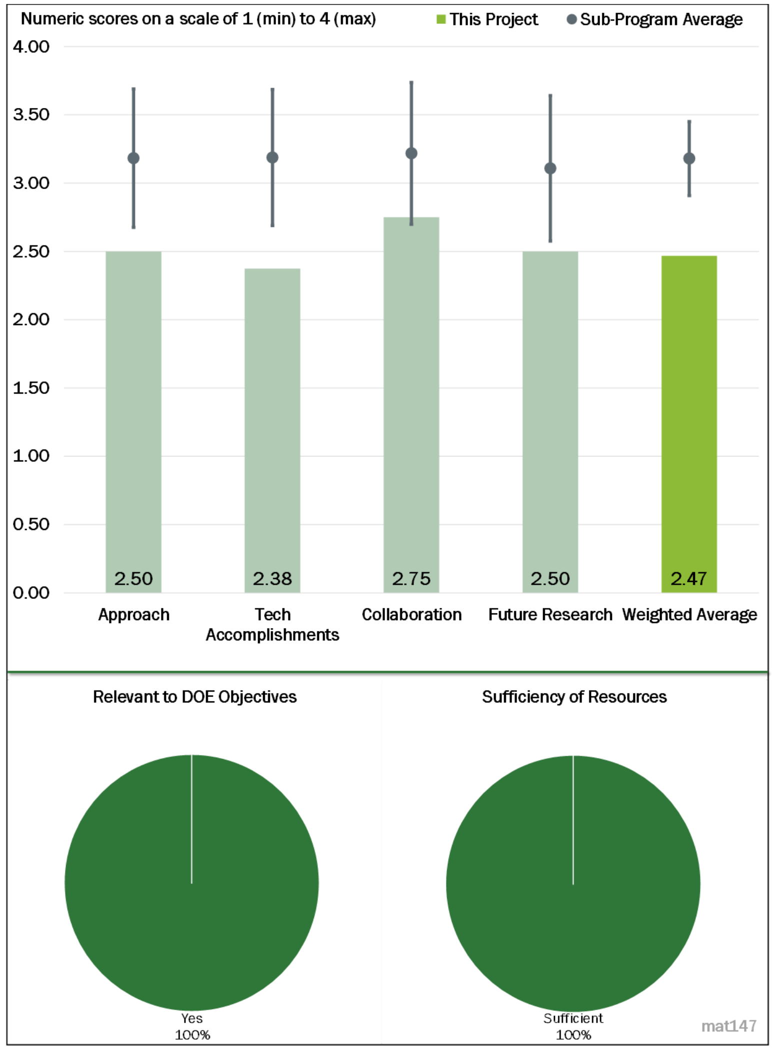

Figure 6-20 – Presentation Number: mat147 Presentation Title: Continuous Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression-Forming Process Principal Investigator: Philip Taynton (Mallinda, LLC)

Presenter

Philip Taynton, Mallinda, LLC

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer said the approach of using pre-cured malleable thermoset prepregs for composite manufacturing is novel and will help industry to reuse the material. This reviewer is not sure why the split-Hopkinson pressure bar (SHPB) was proposed to understand the energy absorption. There are several easy tests already available and the reviewer questioned why a complicated test was chosen.

Reviewer 2:

This reviewer indicated that overall, this seems like a very new idea, perhaps with some potential (though not a lot of experimental evidence was shown for the potential) but lacking the critical element of composite mechanics. It seemed like a science project: try this formulation with that fiber combination and see what happens. Some mechanics-based modeling and simulation might be able to steer to optimal selections. No evidence was shown for malleability of these materials, which was the first word in the title. There was no clear validation of the compression forming, which was the final major claim in the title.

The reviewer commented that including split-Hopkinson testing does rate the effects, but it was not clear whether the rates achievable with the experimental setup are appropriate to the application space being considered, namely vehicle technology. The Test Machine for Automotive Crashworthiness (TMAC) would provide rates relevant to automotive applications.

Including ultrasonic testing, while promising some kind of quality assurance/quality control, does not seem like a critical issue at this point in the project. The reviewer asserted that far more critical and fundamental questions exist that were completely neglected or treated with a kind of "we might try and see if this works" approach.

Reviewer 3:

The reviewer remarked that the PI introduces the industry to a "new" form of matrix system for composite materials. The "malleable thermoset composite" is a novel approach and with sub 1-minute dwell times established for molding, the material appears to be very interesting on its own merit. This reviewer is puzzled why a broad interrogation of "hybrid" fibers (including steel wire reinforcements) is a necessary part of realizing the malleable thermosetting materials. This reviewer would have benefitted from seeing more data regarding the neat resin properties vis-a-vis industrial amine cured epoxies or industrial thermoplastics such as PA-6, polybutylene terephthalate (PBT) or poly(p-phenylene-2,6-benzobisoxazole) (PBO) to see where it sits in terms of modulus, tensile strength and K1C (fracture toughness). Similarly, some static composite coupon data would be useful (i.e., interlaminar shear strength [ILSS], transverse and shear properties, and G1C) to place this in context with conventional materials in service today. The reviewer said the overall value of the material system is blurred by the approach of evaluating a broad swatch of "hybrid" reinforcements when fundamental work to understand the baseline composite would be such a good starting point. This reviewer would prefer to review the performance of this matrix system with conventional reinforcements and textile architectures that would include high-strength, industrial CF, E-Glass fiber, H-Glass Fiber, and S-Glass fiber. This would provide a baseline for designers to reflect on and might then suggest opportunities with other reinforcements (steel, ultra-high molecular weight polyethylene [UHMWPE], Aramid, etc.).

This reviewer might also question the use of the SHPB for evaluating strain rate dependence in vehicle crash analysis and simulation. Strain rates on the order of 10^4 and higher are evaluated for hypersonic and ballistic performance, but many applications in vehicle crash are represented by strain rates much lower than this. The reviewer said quasi-static punch through shear and falling dart impactors are more appropriate for this interrogation. The high strain rate work is interesting, but to this reviewer, unnecessary unless protecting against ballistic attacks or bomb blasts.

This reviewer also commented that the value of modulus postulated by the PI in the presentation is off by a factor of more than 3. The modulus of industrial grade CF is typically about 240 GPa and the tensile strength is usually about 3200 MPa or about 3 GPa. Similarly, numbers quoted for glass strength are off. Trivial maybe, but it leaves this reviewer wondering about the experience of the team with more conventional composite systems and where they are trying to drive this technology.

Reviewer 4:

The reviewer noted that this is a new project and very early on in the development cycle. Essentially the performers are investigating constituents, a malleable (recyclable) polymer resin in hybrid fibers including carbon, glass, UHMWPE, and steel fibers. Composites made from these are going to test these at high strain rates in a SHPB and in a crash simulator (TMAC). The team's approach is to fast stamp (compression mold) these constituents at high rate and conduct acoustic analysis for defect characterization/quantification. While the idea is generally interesting, there was not sufficient detail to form an opinion on the project (yet). The reviewer remarked the key to the process is the malleability (or reversibility) characteristics of the resin. There was really no information about this and hence it is very difficult to ascertain the scientific quality of the work from a material constituents standpoint.

This reviewer posed a number of questions that were unanswered by the presentation, including how the project team is going to prepreg these materials; whether there are commercial sources to prepreg steel fibers with polymer based fibers; what the material architecture is; the kinds of fiber volume/weight fractions that are envisioned; and the set metrics in terms of energy absorption, impact energy mechanisms, acceptable deformation, and anticipated peak forces. This key information was missing.

While SHPB provides rate-dependent information, the reviewer also inquired about the strain rates being considered in this work; the makeup/geometry of the specimen; and the prior studies on which this is based. The TMAC has a very different strain rate range and loading mechanism compared to the SHPB, which prompted the reviewer to ask about the rationale of these two set ups and the applications that each would most represent. The reviewer remarked this was rather sketchy.

The project team mentioned fast stamping and acoustic analysis and inquired about the types of defects that are expected to occur; and what the general processing conditions are (e.g., heated platens, heated tools, shapes, sizes, or process cycles). Again, the reviewer found that this key information was missing.

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

Reviewer 1:

The reviewer noted that it was claimed that a resin was successfully developed. It was stated that resin met the targets, but the results were not provided. The targets and results achieved were not provided to understand the success of the development. For example, the value of minimum interlaminar shear strength, which is one of the important targets, was not specified.

Reviewer 2:

The reviewer commented that the issue of the resin bonding to the fiber, e.g., the interface, seems to be a key technical issue and was not addressed, except indirectly in the statement about permeation of the UHMWPE. This reviewer imagined this would also be a key issue to understand and address.

Another critical parameter is the vitrimer transition temperature (T_v), tied to the glass transition temperature (T_g) The presenter stated that the team can adjust the T_g (and thus the T_v) of the resin. However, it seems likely that because of trade-offs, only certain combinations of Tv will be available to bond with a given type of fiber. It would be helpful to understand what composites actually have been developed and what the properties are, both mechanical and thermal. If few combinations have been developed to-date, perhaps modeling could guide at least a realistic sense of what may actually be possible, both in terms of thermal and mechanical properties.

The statement was made that because of the specific resin chemistry, the composite will have selective chemical sensitivity. This would appear to be a key technical point and should be at least elaborated, if not more thoroughly addressed. The reviewer asked what the resin is sensitive to and what applications will and will not work with that sensitivity.

Then reviewer noted the presentation claimed increased formability of composites utilizing this resin. Images were shown of what appeared to be a generic forming mold and composites formed in this mold. However, it was unclear if these were materials that featured the resin and fiber systems being discussed or were just stock images. Further, moldability was never discussed further, though it was a major claim in the title of the presentation. This reviewer would be interested to know what forming experiments have been conducted on composite materials generated in the study.

It was unclear from the presentation whether composites with multiple fiber types, e.g., glass and carbon in the same composite, were being considered. This is a topic that has received treatment in the past, with claims that different strains-to-failure may increase energy absorption relative to a solely-carbon system. Such claims are still being investigated and while it is hoped that hybridization may increase the design space, composite mechanics provides realistic bounds. Namely, addition of a second fiber type (e.g., glass) displaces that much carbon, thus lowering the performance proportionally. Furthermore, micro-mechanical stress analysis reveals that the stiffer fiber will carry a proportionally higher load and with decreased volume fraction, and fracture that much sooner. The reviewer said the purpose of this comment is to underscore again the need for composite mechanics in this composite formulation exercise.

If a person is selecting a material, it would be helpful to understand how this material compares with traditional thermoset and thermoplastic composites. This person would be interested in understanding thermal and mechanical properties, and formability of composites with this resin system compared to candidate thermoset and thermoplastic systems. For example, pick a few combinations: carbon-epoxy, glass-PA and glass-PP and compare against a carbon-reinforced and a glass-reinforced system using appropriate novel resins.

Reviewer 3:

The reviewer indicated the total funding for this project is relatively modest and the technical progress reported is in line with the funding level. The effort is to interrogate multiple (70 is reported) formulations. It is disappointing that the targets are not specified in the reporting (it is assumed these are still considered proprietary, but this reviewer would question why), but the reported targets of compression required, glass transition temperature, ILSS, moisture absorption, and adhesion characteristics are set. This reviewer is left wondering about modulus and tensile strength as well as fracture toughness and strain to failure. These are important characteristics of a matrix in impact conditions.

Using ultra-sonic inspection techniques (including C-Scan ultrasonic inspection) are well established for composite laminate inspection and quality assurance. This reviewer explained that more data related to the level of consolidation, dwell time, and temperatures would have been useful to assess the sensitivity of process parameters.

Reviewer 4:

This reviewer referenced “Resin Development” on Slide 10, which mentions targets were achieved, 70 formulations were tested/developed, and adhesion to UHMWPE, etc. No information is provided about what constituted meeting targets; and what were the differences/makeup/design of experiments to make up the 70 formulations. This reviewer asked what was unique about the resin that enabled it to attach to the low surface energy UHMWPE. The reviewer explained that companies have spent years enhancing the interfacial bond strength of olefins to substrates, and this work should have given some level of confidence to the reviewers rather than just the blanket statements that were made. Regarding the Under Fiber/Composite information on Slide 11, this reviewer commented that some web-based pictures of weaves were provided, without any basis or rationale for the choice for the particular application, weave architecture, prepregs formation, etc. Slide 12 provides a general C-scan without any information about the volume/weight fraction, resin viscosity, processing conditions, thickness, void percentages, etc. Subsequently, the reviewer asked what one can tell from this C-scan beyond just seeing the weave architecture, and also inquired about the sample/material constituents that are in these. Overall, the reviewer indicated that technical accomplishments were not backed by sound/scientific rationale (or at least as presented).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer observed good collaboration among the National Laboratories, but the project is missing an industrial partner who can provide the key requirements for successful resin development (e.g., glass transition temperature, interlaminar shear strength, etc.). As the project started recently, the reviewer suggested including an industry partner to help in productionizing this technology.

Reviewer 2:

The reviewer commented that the PI has identified a strong team and reported initial results with contributions for members of this team. No significant problems are noted between the collaborators. It was unclear to this reviewer whether the PI has the time and experience working in composite materials based upon some of the technical approach and nomenclature used as well as the need to baseline matrix properties in the composite system. It is expected that the ORNL connection in close collaboration might close some of those gaps.

Reviewer 3:

The reviewer noted that it was very early in the project to make a judgement of the nature of the collaborations. It appears that ORNL is a partner because of the TMAC, while Sandia has the SHPB capabilities, and Pacific Northwest has the acoustic analysis capabilities.

Reviewer 4:

This reviewer remarked that while collaboration exists, it appears to be the wrong collaboration. Namely, as discussed above, an absolutely critical element of this kind of project is composite mechanics. That was completely missing. The included element of ultrasonic scanning, while perhaps useful later down the road, appears completely unnecessary here. At least, no real insight from the scanning has yet been developed.

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:

This reviewer stated that for determining the energy absorption, SHPB testing may be too complex. The sample geometry and testing conditions may provide significant challenges. Drop tower testing might be more reliable to understand the energy absorption.

Reviewer 2:

The reviewer asserted that compression forming development is critical. This reviewer expected evidence of compression forming to be presented already, as this is definitely a needed piece. The C-scan piece is secondary, at best. Far more important is selection and documentation of material combinations that have appropriate mechanical and thermal properties and exhibit appropriate formability. The reviewer indicated that high-speed impact testing is of secondary importance, though the TMAC testing will be important. However, before any of these dynamic tests, it would be helpful to have a suite of static mechanical and thermal tests to establish baseline properties for comparison with other, standard and commercially-available, thermoset and thermoplastic materials.

Reviewer 3:

This reviewer observed that the proposed future research addresses compression forming development but does not directly address the "remaining barrier" noted of bond exchange during consolidation. It addresses correlation between observed ultrasonic testing results and mechanical performance. A bit of a disconnect. This reviewer encouraged the interrogation of conventional fibers (in replacement of or in addition to hybrid constructions) to allow for comparison of the matrix contribution to enhance TMAC performance.

Reviewer 4:

The reviewer noted that the proposed future research is provided in a very vague manner and here again it is hard to make any comprehensive judgement. Basically, it just says the team will do compression forming, without giving any indications of what the makeup of the hybrid fabrics is, which resin types (out of the 70 that will be considered), which process conditions, or any such information.

The reviewer asked on what the team will perform "High Speed impact testing of various hybrid fabric composite designs & lay-ups for down-selection." The reviewer further asked what strain rates will be used, why, what the team expects to learn from these, and what they will be looking for.

Regarding TMAC testing and correlation with high speed impact results, the reviewer referenced the same comments as above.

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

Reviewer 1:

This reviewer noted that the project illuminates a new approach to formulating a thermosetting matrix for composites that support rapid molding operations with what appear to be interesting and favorable toughness properties. This alone supports many of the objectives of the DOE and the implications for economic manufacturing of lightweight components for vehicles and transportation systems. The current project takes this further by investigating the impact characteristics, and if shown to extend performance and improve safety, will allow for faster adoption in vehicle systems.

Reviewer 2:

This reviewer said that vitrimers are novel materials and have potential to be multifunctional resins (both thermoset and thermoplastic) with recyclability. This project is very much relevant to support the DOE objectives of reducing the material cost of lightweight composite materials.

Reviewer 3:

This reviewer said the DOE objectives called for recyclability, lower carbon footprint, and low-cost solutions. These were not captured in this briefing. Perhaps it is too early on in the program, but it is a shortcoming.

Reviewer 4:

This reviewer said that in its broadest sense and as titled, yes, this project supports the overall DOE objectives. However, as noted above, this reviewer does not agree with the execution of the project. In its current form, it is hard to see how the current work is contributing directly to DOE objectives, though the reviewer would give it time to play out, especially with the addition of missing elements detailed above.

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 sufficient resources to complete the project.

Reviewer 2:

Resources appeared sufficient, from this reviewer’s perspective, to complete the work outlined by the PI.

Reviewer 3:

This reviewer was unsure if the budget can afford it, either through redirection of existing resources or addition of further resources, but including a partner with specialty in composite mechanics would provide significant value to the project, making the current investment go significantly further with little cost relative to the value added.

Reviewer 4:

This reviewer noted that there are resources across the collaboration. It was not clear what processing capabilities exist with the company, and what aspects of the fabrication will be done elsewhere. Again, it was hard to say from this reviewer’s perspective.

Presentation Number: mat149
Presentation Title: Non-Rare Earth Magnesium Bumper Beams
Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

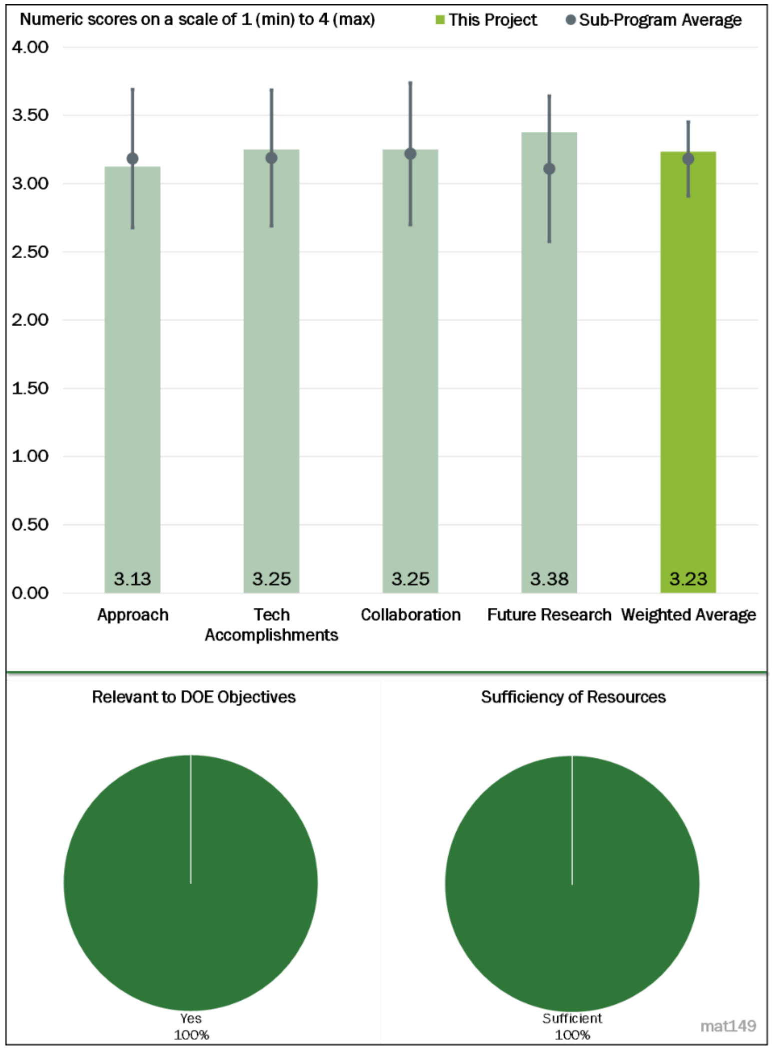

Figure 6-21 – Presentation Number: mat149 Presentation Title: Non-Rare Earth Magnesium Bumper Beams Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

Presenter

Scott Whalen, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer stated that the project uses the Shear Assisted Processing and Extrusion (ShAPE) solid state processing technique to make rectangular cross section Mg bumper beams. The approach is sound.

Reviewer 2:

This reviewer stated the project addresses barriers in Mg energy absorption and cost without rare-earth elements by using ShAPE processing of a Mg profile. All questions were answered with knowledge and confidence.

Reviewer 3:

The reviewer stated that Mg can be a potential candidate for weight saving and this project is aimed to develop a process to manufacture wrought Mg. The process promises the possibility of less texture, which influences the performance of wrought Mg. The potential had been demonstrated in smaller tubular sections and being expanded to larger irregular sections.

Reviewer 4:

This reviewer stated that the technical barriers of energy absorption and fabrication of Mg extrusion are addressed. It is not clear how significantly the removal of rare-earth elements will affect cost.

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

Reviewer 1:

The reviewer observed that at this early stage of the project, no obvious barriers to progress were identified. A great deal depends on being able to successfully create structurally sound rectangular cross section, but as that is the primary question this does not seem like a major roadblock.

Reviewer 2:

This reviewer stated that the project started at the beginning of 2019 and is currently 13% completed and on track.

Reviewer 3:

This reviewer stated that a new emerging process is being used to extrude Mg hollow sections. The challenges include tool design and fabrication. No new alloys are being developed. This process development can benefit many Mg wrought alloys that have high strength.

Reviewer 4:

This reviewer noted that progress to date is limited, because the project started in the beginning of calendar year 2019.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer stated that the project only has two partners—a process developer and an end user. This should be adequate, as the technology can be easily transferred to the industry partner who can implement it very easily.

Reviewer 2:

This reviewer said the project shows good collaboration between a National Laboratory and industry in a LightMat cooperative research and development agreement (CRADA).

Reviewer 3:

This reviewer noted that all collaborations and partners were identified with roles and responsibilities listed.

Reviewer 4:

The reviewer commented that this is hard to assess, as much of the initial work is housed at one institute (PNNL).

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

Reviewer 1:

This reviewer remarked that the proposed plan is excellent and, if successful, this will be high impact work.

Reviewer 2:

An effective project plan was observed by this reviewer.

Reviewer 3:

The reviewer indicated that it is not clear how the lower cost will be assessed in this project, nor how significant the cost reduction can be.

Reviewer 4:
This reviewer stated that scaling up is the proposed work. The design of the port hole die for extrusion is not an easy task and the team is not mentioning how they plan to approach this. The team needs to approach an extruder or engineering firm who are experts on this.

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

Reviewer 1:
This reviewer stated that greater than 30% weight reduction can be achieved by replacing Al bumper beams with Mg beams. The impact on weight saving and fuel economy will be substantial.

Reviewer 2:
This reviewer stated that Mg is the most cost-effective solution for lightweighting, but many technological issues need to be resolved before it becomes cost effective. The fracture behavior of Mg components under dynamic loading is one of those issues where conventional alloys fail in a catastrophic manner. This project is developing a process which can make the Mg bear the load more effectively, similar to Al or steel. This could be a good progress if it can be scaled up.

Reviewer 3:
This reviewer said that in order to realize reduction in weight with use of Mg alloys, texture engineering of the Mg is needed to meet energy absorption targets.

Reviewer 4:
This reviewer indicated that the technology is relevant; however, it would be far more interesting and relevant for automotive if this was an Al alloy project.

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

Reviewer 1:
This reviewer commented that most of the resources are currently in operation.

Reviewer 2:
This reviewer stated that the resources are sufficient for the plan presented.

Reviewer 3:
The reviewer observed sufficient resources.

Presentation Number: mat150
Presentation Title: Low-Cost Corrosion Protection for Magnesium
Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

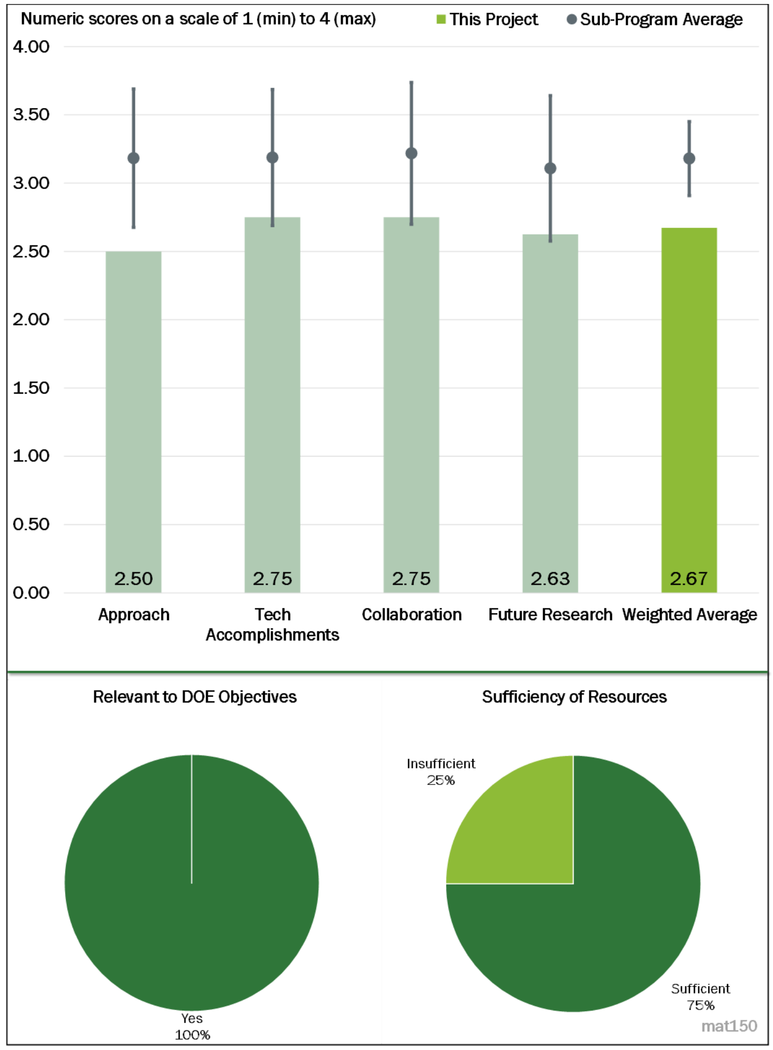

Figure 6-22 – Presentation Number: mat150 Presentation Title: Low-Cost Corrosion Protection for Magnesium Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

Presenter

Aashish Rohatgi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer noted that the project investigates an observation on a difference in Mg corrosion and is attempting to find the mechanism. There is not an obvious strategy in the approach for which characterization method to try, but the tests to date seem reasonable. More surface chemistry characterization techniques than currently proposed may be useful, but this type of work does seem more suited to a trial and error approach than others. This reviewer suggested a more systematic approach (or presentation) to help identify which mechanisms are still possible, and which have been eliminated.

Reviewer 2:

The reviewer stated the project is fairly new, because it started in January 2019. Surface modification with a laser is claimed to reduce the susceptibility of Mg to corrosion. Experiments support this claim but no clear hypothesis has been postulated to guide the effort. The title claims that the approach is low cost, but of course lasers are not a low-cost solution. It is understood that the team wants to elucidate the fundamental mechanism behind the experimental observations, but it is quite surprising that this effort received funding without a hypothesis based on more complete experiments than the ones presented here plus any insight from relevant literature.

Reviewer 3:

While it is clear little time has passed since the project start, this reviewer commented that major questions related to the general approach taken remain unclear. As an initial example, the reviewer highlighted the lack of a clear analysis of what surface condition the laser treatment results in; it is unclear whether the improved corrosion resistance is due to a cleaning effect of the surface. It would therefore be beneficial to ensure that clean starting material (by chemical etching or polishing) is used. Another example is that the economic benefit of a coating process is not clear. The reviewer asked how the costs of a laser treatment compete with chemical conversion coatings. As a final example, the reviewer asked if glancing incidence X-ray diffraction (GI-XRD) is a suitable method to characterize the improved corrosion resistance.

Reviewer 4:
This reviewer commented that while the project approach does attempt to address the gaps from the “Overview” slide of “Lack of cost-effective, durable protective coatings” and “Current technology using organic coatings require multiple steps and chemical baths to improve adhesion and porosity-free coatings,” the project does nothing to address the gap of “Lack of corrosion resistant magnesium (Mg) alloys.” This is not a major issue, but should be corrected on the Overview slide before the next review.

Nothing in the presentation seems to identify the underlying thought process of why the surface modification (reducing/removing $Mg(OH)_2$ and MgO) is expected to improve corrosion resistance. While the presentation notes improved atmospheric corrosion resistance in surface-modified AZ31B sheet, this does not necessarily mean the surface-modified material will exhibit improved corrosion resistance in aqueous environments (especially with salt), which is the primary source of corrosion damage occurring to automotive components. The reviewer said that while it may be that this surface modification can substitute for a chemical cleaning and pretreatment prior to coating without the commensurate environmental damage, it does not seem completely clear that this is what the project is proposing, nor does there appear to be any plan to evaluate this process and compare it to more conventional pretreatment/coating configurations.

Additionally, affordability and commercialization of the proposed process are substantial concerns. The presenter's comment that the intended purpose is to learn why the surface modification works, rather than actually proposing its use as practiced, makes this a little more palatable.

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

Reviewer 1:
Because this is a new project, this reviewer would not expect many results at this time. However, the analysis of as received and surface-modified AZ31 does show improved atmospheric corrosion resistance with reduced Mg hydroxide formation. How this will correlate with salt spray corrosion tests or (potentially) coating adhesion remains to be seen.

Reviewer 2:
This reviewer said that with a “fishing expedition” (not intended as a negative opinion of the work) such as this project, assessment of the progress and accomplishments are difficult.

Reviewer 3:
The reviewer stated that the progress made so far is limited and insufficient to gauge the merit of this project.

Reviewer 4:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer said that no limitations were reported/apparent.

Reviewer 2:
This reviewer stated that all collaboration partners are from research labs and academia. Industry participation could help to guide the project to ensure any improvements are meaningful for real world automotive corrosion environments, but no industry partners were identified in the presentation.

Reviewer 3:
This reviewer said the presentation largely left the responsibility of the different institutes unanswered.

Reviewer 4:
It was not clear to this reviewer (from the presentation) what specific contributions the Universities of Oregon and Iowa are supposed to make to the project.

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

Reviewer 1:
This reviewer stated that while the project does propose future work to identify, characterize, and better understand the mechanisms of corrosion mitigation related to surface modification, and does propose to begin working with industry partners, the team still seems to be putting too much faith in the surface modification to provide corrosion protection by itself. The reviewer said it seems that there should be a substantial effort to determine how well this surface modification will work with coating technologies rather than expecting it to provide sufficient corrosion protection by itself.

Reviewer 2:
This reviewer noted that the PI proposed to determine the mechanisms behind the experimental observations. Without some guiding principles, it is difficult to anticipate whether the team will successfully elucidate the mechanisms and at the same create a cost-effective alternative to coatings.

Reviewer 3:
This reviewer said that an improvement of the work to answer the previously mentioned questions would be ideal.

Reviewer 4:
This reviewer said again, it is hard to assess.

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

Reviewer 1:
This reviewer said the project is clearly relevant to helping to increase the use of Mg, the lightest structural metal in automotive applications, by improving corrosion performance—one of the primary obstacles to more Mg use.

Reviewer 2:
The reviewer stated that the topic itself remains an important field of work.

Reviewer 3:
This reviewer said that new ways to mitigate corrosion in Mg sheet alloys appears to be of interest to VTO.

Reviewer 4:

This reviewer would have preferred a non-yes/no reply in this case. If the mechanism for improved corrosion research can be found, and it is commercially viable, then yes. Otherwise, it is more of a curiosity to this reviewer, who indicated that the only way to find out which it is would be to do the work.

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

Reviewer 1:

This reviewer stated that the resources appear to be sufficient to conduct the tests proposed.

Reviewer 2:

This reviewer stated that no shortages in resources seem apparent.

Reviewer 3:

This reviewer said that again, it is hard to assess given the open-ended nature of the project.

Reviewer 4:

The reviewer indicated that project timing does not appear sufficient for a project with this many unknowns. Additionally, the project needs at least one to two industry partner(s) to help guide it and make sure the work has some ultimate potential for use in a high-volume commercial environment. The proposed future work mentions this, but no additional partners were identified in the presentation.

Presentation Number: mat151
Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints
Principal Investigator: Adam Powell (Worcester Polytechnic Institute)

Presenter

Adam Powell, Worcester Polytechnic Institute

Reviewer Sample Size

A total of three reviewers evaluated this project.

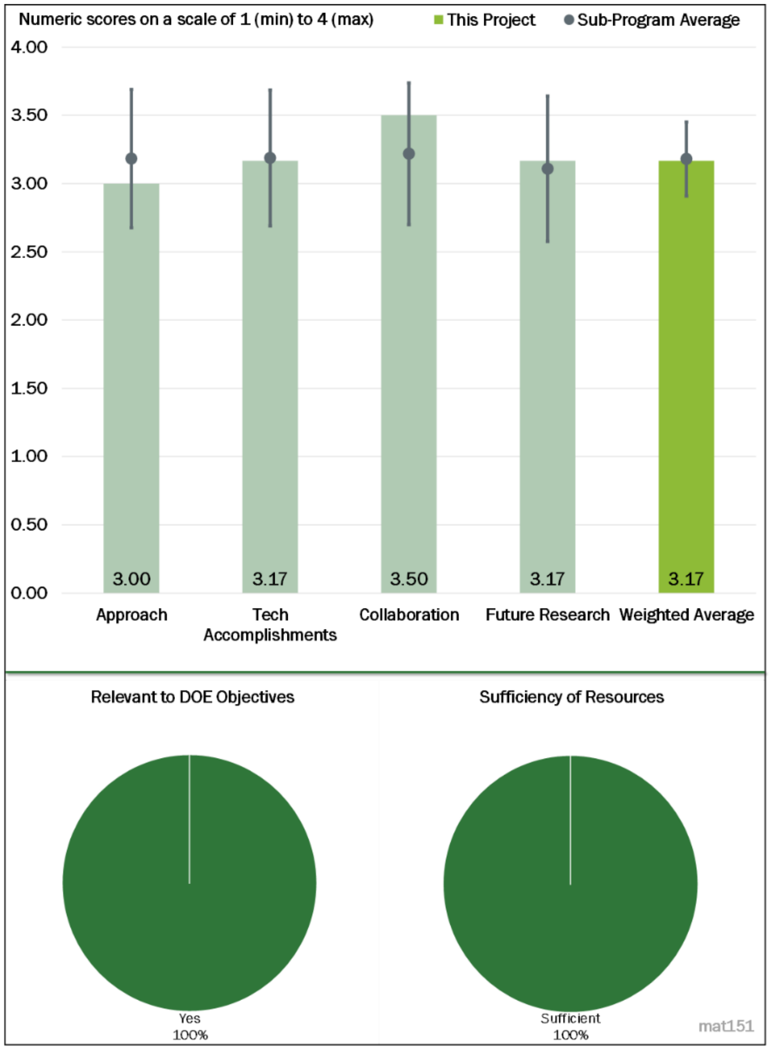

Figure 6-23 – Presentation Number: mat151 Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints Principal Investigator: Adam Powell (Worcester Polytechnic Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer said the approach presented seems to be reasonable and sound, while a closer link could be drawn to the actual case study presented serving as an application example (door).

Reviewer 2:

This reviewer stated that the approach is generally good and will answer many of the questions posed. The reviewer offered a few suggestions for the PIs to consider. Firstly, addressing FSW in more detail because perfecting or using the proper FSW parameters is of paramount importance to the quality of the welds/joints obtained. Secondly, thoroughly consider the issue of model validation. The reviewer asked how the model(s) to be developed is/are going to be validated. It was mentioned during the question and answer session after the presentation that experimental data were to be used for validation. The reviewer explained that careful consideration should be given to this approach so as not to limit the bounds of the model to that which can be validated by what may turn out to be limited experimental data. A high-quality, independent set(s) of data (separate from those collected by the project team) will assist in forestalling this possibility. Thirdly, it was not very clear whether the model to be developed would correlate microstructure to corrosion performance as well as mechanical robustness/behavior. If both, the reviewer commented that the model(s) must then include elements of electrochemistry, including surface reaction, and fracture mechanics. If not, the reviewer requested that the project team please explain.

Reviewer 3:

Generally, this reviewer found that the project approach addresses most of the stated technical barriers. However, the reviewer expressed concern about the apparent assumption that FSW of the Al and Mg alloys will be successful, and therefore, the primary challenge will be modeling the corrosion behavior. A literature review shows that Al to Mg FSW suffer from brittle intermetallic formations. Development of welding process parameters and addressing any associated challenges/complications should be clearly identified in the project timing and milestones with appropriate mitigation plans or alternate paths identified. In this reviewer's opinion, FSW of Al and Mg is a significant challenge in its own right that could potentially merit its own project. It seems risky to base the corrosion modeling portions of the project on such a challenging joining configuration.

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

Reviewer 1:

This reviewer said the progress made seems to be in line with the project plan.

Reviewer 2:

This reviewer stated that this is a new project that is 10% complete. However, initial steps taken are promising and in the right direction.

Reviewer 3:

This reviewer said the project has only recently started, so not much progress is expected at this time, and not much is reported.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said that the project has a good selection of collaborative partners with complementary roles that seems appropriate for the scope.

Reviewer 2:

The reviewer commented that the team appears to be solid and well-rounded with complimentary skills.

Reviewer 3:

Despite the large team, a good level of co-working seemed to be apparent from this reviewer's perspective.

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:

This reviewer said the proposed future work catches most of the primary concerns of the reviewer.

Reviewer 2:

The reviewer remarked that this project seems to have effectively planned its future work in a logical manner. However, the risk of not achieving good welds of the Al to Mg suggests the need for a decision point and potential alternative in case this process is not successful.

Reviewer 3:

This reviewer said please consider comments made in the approach section in reviewing the direction of future work.

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

Reviewer 1:

The reviewer stated that this work is important to the development of dissimilar metal welds for auto body construction, which is important in reducing auto glider weight.

Reviewer 2:
The reviewer stated that incorporating and extending modeling techniques is a valuable contribution to this research field.

Reviewer 3:
The reviewer stated that the project addresses the need to predict general corrosion of Mg and Al alloys and galvanic corrosion of joints incorporating these two lightweight materials.

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

Reviewer 1:
No insufficiencies were reported by this reviewer.

Reviewer 2:
The reviewer indicated that this project seems to include appropriate budgetary and collaborative resources to achieve its goals. Project timing is likely to be a bigger challenge.

Reviewer 3:
This reviewer stated that the resources appear to be adequate. However, the project is only 10% complete, so still early in the process to make a good resource assessment. Also, there is no information on how much money has been spent for the 10% of work done.

Presentation Number: mat152
Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives
Principal Investigator: Roozbeh Dargazany (Michigan State University)

Presenter

Roozbeh Dargazany, Michigan State University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

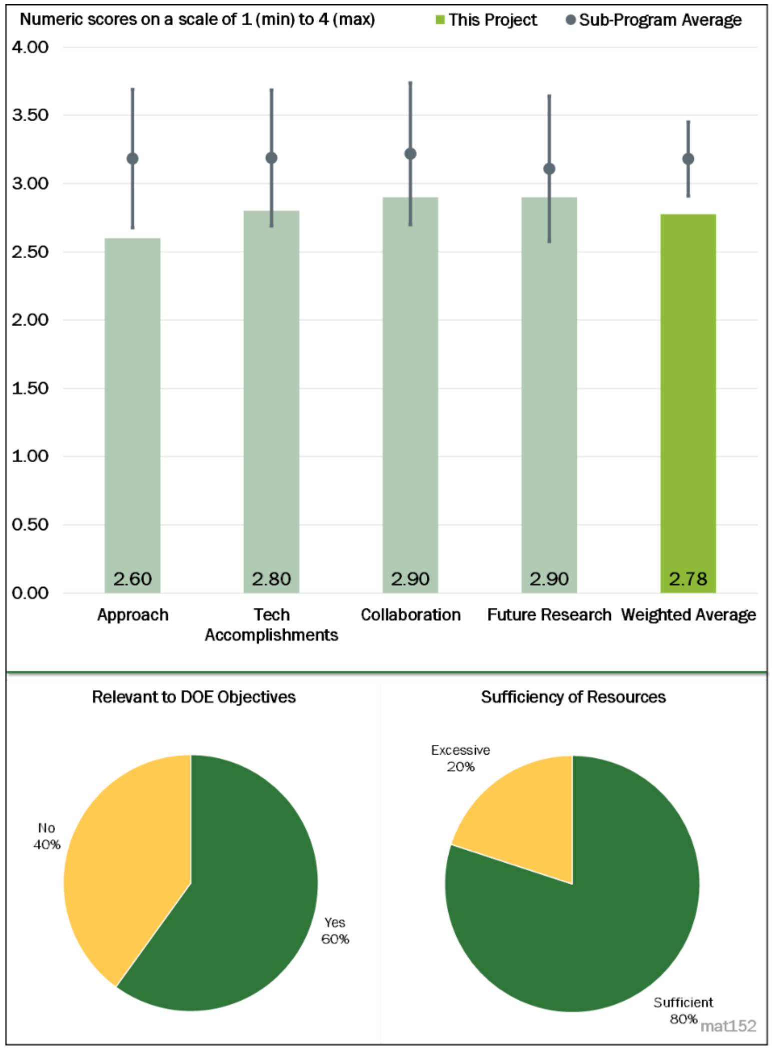

Figure 6-24 – Presentation Number: mat152 Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives Principal Investigator: Roozbeh Dargazany (Michigan State University)

Reviewer 1:

The reviewer commented that the project approach is appropriately, or perhaps overly, aggressive and incorporates elements necessary to show significant progression towards a challenging set of issues. As outlined, the approach is logical, but will need to be better defined, prioritized, and tweaked as the project progresses. The breadth of the approach is impressive, but it is not clear how the progress gets integrated for a cohesive tool or set of tools.

Reviewer 2:

The reviewer remarked that it would have been great if the elements of damage mechanism identified to real world examples of adhesive joining used in automotive body construction. Adhesives have been used in automotive vehicles extensively since the late 1990’s and this reviewer is not sure whether the damage mechanism of joints/adhesives can be all related to the mechanism listed for the approach.

Reviewer 3:

This reviewer was unsure if the project plans to study corrosion-induced failure in cross-linked adhesives, and reported that it studies all failure modes of networked structured adhesive.

Reviewer 4:

The reviewer stated that the proposed work aims to start from collecting own experimental to be used in the modeling. But it is not clear what the minimum critical number of experiments is that needs to be collected to achieve a specific level of the target accuracy. Also, features to be used in the neural network model are not discussed enough. If scientific features are not included, but only simple superficial ones are used, then neural network models can easily become a black box surrogate model. If the sole intention is developing a highly accurate predictive model, then the reviewer suggested performing massive high-throughput experiments to collect a large volume of data for model training. However, such neural network models cannot be transferred to other systems and are only valid in the very system where data have been collected. The reviewer commented that the project should be more focused on selecting/identifying features that can efficiently capture the underlying mechanics/physics/chemistry of the system.

Reviewer 5:

The reviewer stated that the research project is attempting to model the degradation and failure mechanism in adhesively bonded mixed material joints. However, it seems that the project is focusing on the incorrect failure mechanism of these joints. Their research is aimed at understanding the degradation of the adhesive due to various environmental loads. However, in practice, mixed material (or like material) adhesive joints do not fail by degradation of the adhesive, the joints fail by corrosive undercutting at the adhesive-substrate interface. If the joint is not exposed to a corrosive electrolyte, the joints will last for a very, very long time. As such, the research will not be beneficial to the automotive industry, as the researcher has focused on an irrelevant part of the problem.

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

Reviewer 1:

The reviewer noted that this is a new project where it is too early to assess accomplishment and progress. This reviewer is looking forward to seeing how things come together.

Reviewer 2:

This reviewer said that although this project is in the early stages, good progress is being made on publication. However, without knowing the relevance to the proposed work, it is hard to gauge the success.

Reviewer 3:

This reviewer is struggling with the selection of the adhesives for the project and how that relates to use of such adhesives for body-structure applications or sheet metal components in the body where corrosion and damage needs to be much better understood.

Reviewer 4:

The reviewer noted that this is a new project and the preliminary data already produced a journal paper. The team is highly motivated and needs proper steering towards the actual goal.

Reviewer 5:

The reviewer stated that this project has just started, so there are not many accomplishments to show. However, the planned project goals are misguided.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said the upfront planning accounts for successful collaboration among several discrete organizations having vested interest in long-term success. However, it is too early to assess how well this collaboration is being executed.

Reviewer 2:

This reviewer believed the project team can benefit from having input from car manufacturers or National Laboratories supporting the DOE joining technologies.

Reviewer 3:
This reviewer noted that it is a new start. It will need time to evaluate collaboration and coordination across the project team.

Reviewer 4:
This reviewer said that it is good to have multiple teams in the project, but it is hard to understand how the individual team's tasks are interconnected from the org chart. It is recommended to include data input/output flow chart among team members in next year's presentation.

Reviewer 5:
Although the project team seems well coordinated, this reviewer is concerned that there is a lack of understanding about the state-of-the-art in this area.

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

Reviewer 1:
This reviewer stated that the project is just getting started and appears not to have yet encountered major roadblocks needing mitigation. Plans appear adequate to provide useful modeling coupled with experimental approaches resulting in tools and especially data useful to this community. This reviewer appreciates the stated target of the ultimate result being a commercial software package.

Reviewer 2:
This reviewer said the scope of the proposed tasks is broad and comprehensive. It appears a bit overambitious, but the progress can be measured at the next year's review.

Reviewer 3:
Although future proposed work is aligned with the project plan, this reviewer pointed out that relevancy to joining with adhesives for automotive construction is missing.

Reviewer 4:
The reviewer stated that the future research is well outlined in this presentation, but the corrosion data collection at the adhesive-metal interface is not planned.

Reviewer 5:
This reviewer noted the research is not properly focused on the actual failure mechanisms that occur during service of adhesively bonded joints. The research team proposes to break down the degradation of the adhesive into three parts: hydrolysis; thermal oxidation; and photo-oxidation. These mechanisms are inconsequential to the degradation of adhesive joints, which typically fail by corrosive undercutting. Commercial adhesives are quite resistant to hydrolysis. Photo-oxidation does not occur in adhesive joints, as the adhesive is constrained behind opaque substrates. Thermal oxidation can occur, but would be controlled by oxygen diffusion into the joint, which the researchers have not proposed to study. The reviewer highlighted that researchers seem unaware of the large body of literature on polymer degradation. The team also seems unaware of what may be the failure mechanism of these joints.

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

Reviewer 1:
This reviewer said the scope of the proposed research is highly relevant to DOE objectives.

Reviewer 2:
This reviewer said the project demonstrated relevance to DOE. Understanding and implementing effective adhesive solutions are key to lightweighting of vehicles for energy savings. In developing and making integrated computational tools for predicting adhesive damage/lifetime, success in this project will facilitate implementation of new lightweighting methodologies.

Reviewer 3:
The reviewer described this adhesive damage/failure study as well-planned and relevant to lightweight materials research.

Reviewer 4:
This reviewer pointed out that the project lacks partners such as automotive manufacturers, National Laboratories, and adhesive suppliers that have worked in the area of joining with adhesives for years.

Reviewer 5:
This reviewer asserted that this research does not support the overall DOE objectives. This reviewer's understanding of the objectives is that DOE wants to enable the use of lightweight materials on automobiles and other transportation vehicles so that fuel economy is improved and carbon dioxide (CO_2) emissions are reduced. The research in this proposal assumes that the adhesive (polymer) degrades over time and leads to failure of the adhesive joints. This is simply not true. These joints fail by corrosive undercutting of the adhesive at the adhesive-substrate interface. First, the researcher claims that corrosion is being studied, but the researcher is studying the degradation of the polymeric adhesive by hydrolysis, thermal oxidation, and photo-oxidation. The reviewer is concerned that the researcher's use of the terms corrosion and degradation of polymers as equivalent descriptions are indicative of a lack of understanding of the difference.

Second, this reviewer remarked that one of the mechanisms the researcher wants to study is the photo degradation of the polymers. The polymeric adhesives in joints are constrained between two substrates. The substrates are opaque. There is no exposure to sunlight inside of an adhesive joint, therefore the polymer cannot degrade.

Third, this reviewer reported that when questioned by another reviewer, the researcher discussed plans to use a 345 nm light source to study the photo degradation. It has been conclusively shown in literature that you cannot use a narrow spectrum light to simulate degradation by the solar spectrum. The photochemistry will be wrong and one can get both false positives and false negatives by using the wrong light source. The reviewer explained that this is very well known in the photo degradation community. The reviewer stressed that, of course, studying the photo degradation is wrong in the first place.

Fourth, because the adhesive is highly constrained, the reviewer noted that access to oxygen in the joint could become oxygen limited due to the difficulty of diffusing oxygen into the joint. The researcher makes no mention of this. However, this is well known from other areas, such as PV modules, where adhesives and sealants degrade over long time frames but oxygen access is limited. This reviewer added that there are far too many false assumptions in this research to make it relevant to DOE's objectives.

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

Reviewer 1:
This reviewer said it appears a reasonable use of resources given the project partners selected.

Reviewer 2:
The reviewer stated that the funding level is adequate.

Reviewer 3:
Resources appeared in-line with planned activities from this reviewer's perspective.

Reviewer 4:
The reviewer observed an appropriate funding level to perform the proposed research.

Reviewer 5:
In this reviewer's opinion, this research should not be funded. The researcher's premise is false. Adhesive degradation is not the mechanism by which adhesive joints fail in automobiles. When they fail, they fail by corrosion undercutting. Though the terms were used interchangeably in the presentation, these terms are not interchangeable. The inclusion of photo degradation in the research plan is a waste of time and resources. The reviewer said there is no photo degradation in adhesive behind opaque substrates. The researcher plans to use a light source that will distort the photochemical degradation and provide misleading results. The researcher is not including the effects of oxygen diffusion in the highly constrained adhesive.

The researcher is studying the wrong things. Yes, modeling the corrosion of mixed metal adhesively bonded joints would be useful. However, the researcher is not doing that. The researcher is modeling the degradation of the adhesive, not corrosion. Degradation of the adhesive is not relevant—it is not the mechanism by which joints fail. Modeling the degradation of polymers is a well-developed field (people at Sandia National Laboratories, the National Institute of Standards and Technology, and other institutions are good at this).

Presentation Number: mat153
Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints
Principal Investigator: S. Jack Hu (University of Michigan)

Presenter

S. Jack Hu, University of Michigan

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 7: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

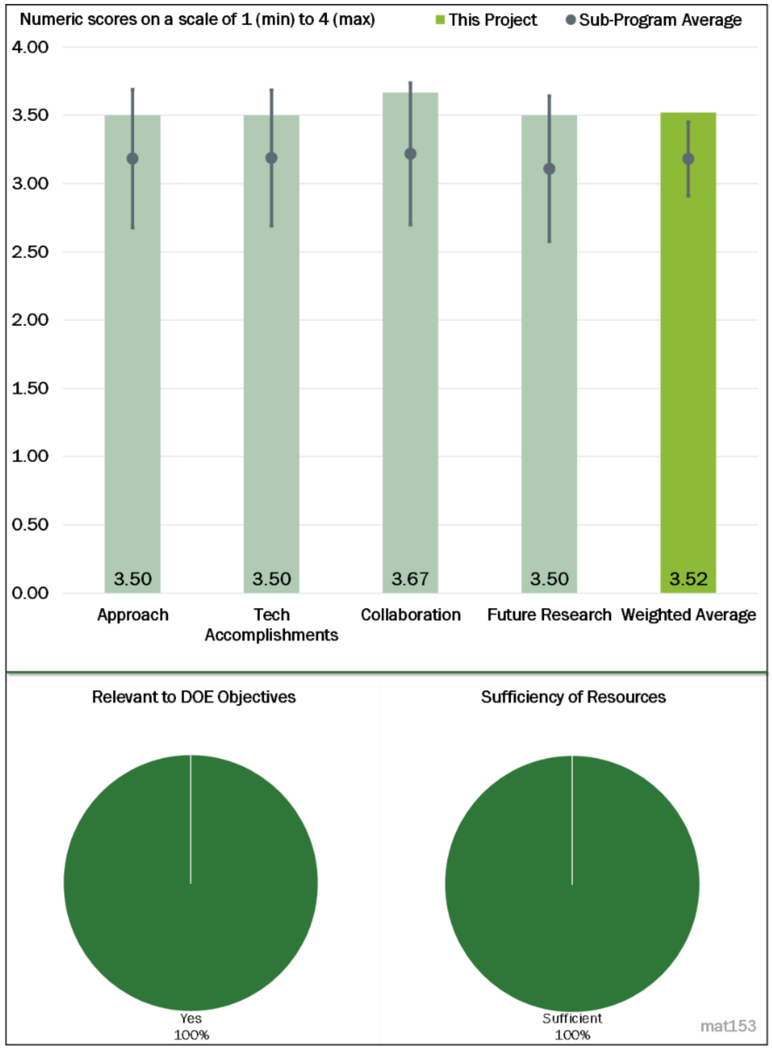

Figure 6-25 – Presentation Number: mat153 Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints Principal Investigator: S. Jack Hu (University of Michigan)

Reviewer 1:

The reviewer noted that this is a new start project to develop a computational platform for modeling dissimilar metal joints. The approach is well designed to start at atomistic levels and, using density functional theory and commercially available software, evolve a computational model incorporating meso and macro-scale data that will allow the prediction of the performance of dissimilar metal joints including effects of corrosion. The reviewer pointed out that these are specific technical targets of the DOE VTO and are identified by the U.S. DRIVE partnership in their roadmap.

Reviewer 2:

This reviewer said the approach involving five steps of multi-scale modeling to solve Al/steel joints' corrosion problem is very well-designed and feasible.

Reviewer 3:

The reviewer stated that the approach seems to be adequate to achieve the objectives set forth in the project. The reviewer provided a few things for the authors to consider: 1) Little detail is given about how the model(s) will be validated. 2) Little detail is given about the loading sequence for fatigue testing, or how the loading sequence will be determined. The correct loading sequence will be instrumental in making sure that the data obtained correctly describe the field condition under which predictions will be made. 3) It is presumed that the atomistic level modeling (with computer coupling of phase diagrams and thermochemistry [CALPHAD] and density functional theory) will include intermetallic formation (thermodynamics and kinetics), which affects corrosion. The reviewer asked what provisions have been made to model thermodynamic as well as kinetic aspects of intermetallic formation at the Al-steel joints.

Question 8: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that it is a new start. The plans shared for this project are excellent.

Reviewer 2:
This reviewer said that for the very short period of performance (about nine months), there has been significant progress in the planning phase for defining configuration of joints, two joining techniques, design of experiments and testing at an original equipment manufacturer, and establishing the detailed requirements for the quantification of corrosion and mapping of its location. Additionally, some preliminary corrosion tests have been performed.

Reviewer 3:
This reviewer stated that only 12% of the project has been executed, so it is still early in the work. The reviewer provided a few things to consider and noted the following: very little was said about the corrosion test results in general; and it appears that some corrosion initiation sites were identified from the GM tests. The reviewer asked if the GM test results were from the testing done on specimens prepared as part of this program, or on specimens from another program. Very little was said about how the weld parameters for the three welding techniques under consideration were optimized. The reviewer asked what the final optimized welding conditions were. Very little was said about the quality of welds obtained from the welds made.

Question 9: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer said there is an outstanding team for collaboration on this project, which included three universities (for early stage research and modeling), a supplier of commercial software, a supplier of the joining technology to be used, and an OEM. This team exemplifies elements needed for acceptance of a joining technology and predictive models for the end user. Close coordination during the planning phase is apparent.

Reviewer 2:
The reviewer noted that the team is composed of six members; three universities and three industry partners, all with complimentary skills. It appears to be a strong and well-rounded team.

Reviewer 3:
This reviewer said the Collaboration and Coordination with Other Institutions is well-planned and nicely presented.

Question 10: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that this is a relatively new start project that has just completed its planning phases. The future research described is exactly what is stated in the approach and strategy to address the DOE VTO technical targets and barriers that will allow acceptance of the technology and models by the end user. The work will be performed in a logical manner with five specific milestones defined for execution of the project.

Reviewer 2:
This reviewer noted that the future research plan is essentially the original research plan approved by DOE and is well-presented.

Reviewer 3:

The reviewer commented that future work focuses on modeling and simulation. However, not enough information is given to determine whether the future research will address the corrosion issues at hand. The reviewer cited as examples what parameters and features in the welds and coupons will be focused on to enable prediction of corrosion initiation from the modeling exercise, will these conditions and/or features be determined at the welding stage (weld parameters) or at the post-welding stage (after the welds have been formed), what role, for instance, will things like the kinetics of intermetallic formation play in corrosion initiation , and will volume fraction and distribution of intermetallic compounds play a role as (of possibly many) in the modeling exercise. The parameters (of focus) which will be used to develop corrosion initiation prediction are not clear. The reviewer advised please be specific as to what the authors are going to do in each of the three modeling and simulation exercises identified in your future work.

Question 11: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that this project directly supports the overall DOE VTO technical targets and U.S. DRIVE partnership (includes DOE) roadmap goals for multi-material joining and predictive modeling for dissimilar material joining.

Reviewer 2:

This reviewer stated that multi-materials joints are needed for lightweight materials. This research supports overall DOE objectives.

Reviewer 3:

The reviewer asserted that this work is important to developing dissimilar metal welds for auto body construction, which is important in reducing auto glider weight.

Question 12: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the funding is $2.0 million for 3 years to fund three universities, a technology supplier and an OEM (with a 25% cost share by industry). This is an average of about $167,000 per year per participant (excluding the software supplier assumed to collaborate only). Considering the principle performers for the development of the experiments and models are the three universities, the resources are adequate for the efforts described.

Reviewer 2:

Adequate resources were observed by this reviewer.

Reviewer 3:

Current resources seemed adequate to this reviewer, who reported that work is only 12% complete. Thus, it is difficult to say at this point whether the resources will be adequate because there is a lot of work still to be carried out. There is also no record of how much of the resources have been spent to calculate if the ratio of work done to money spent is close to one.

Presentation Number: mat156
Presentation Title: Improving Tool Durability and Process Robustness in Assembly of Aluminum and Steel Sub-Components using Friction-Assisted Scribe Technology (FAST)
Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

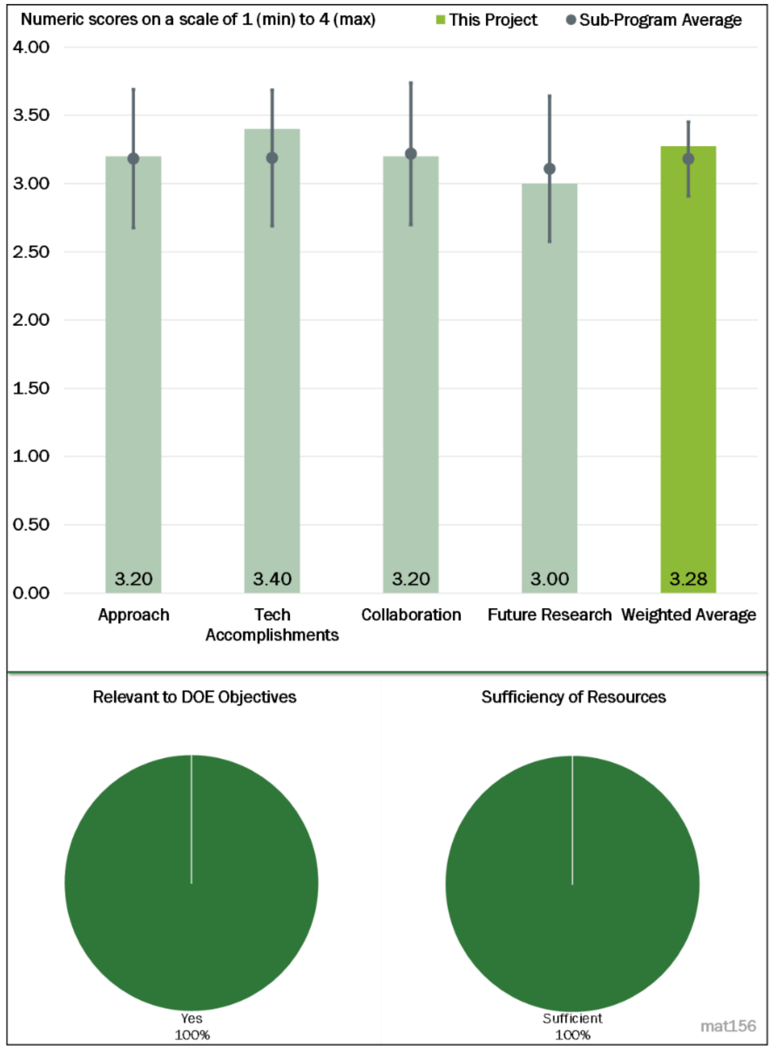

Figure 6-26 – Presentation Number: mat156 Presentation Title: Improving Tool Durability and Process Robustness in Assembly of Aluminum and Steel Sub-Components using Friction-Assisted Scribe Technology (FAST) Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

Presenter

Piyush Upadhyay, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that this is a one-year project that had not started as of the VTO AMR. However, the approach to achieving the objective of implementing friction stir assisted scribe technology (FAST) and addressing the DOE VTO technical target for joining of dissimilar lightweight metals in a high production environment is well defined in a simple two-step process—establish material configurations and baseline welds and optimize the tools and processes needed.

Reviewer 2:

The reviewer commented that this is a great approach. The project has not yet begun, but this reviewer observed a great plan and partners.

Reviewer 3:

This reviewer noted that the presenter outlined several opportunities for investigation in implementing FAST in a production environment, including increasing tool life through choice of tool material, which does not bond as easily to the high strength steel, and friction stir parameters which would enable high elongation welds.

Reviewer 4:

The reviewer stated that this is a new project that investigates the use of a friction stir assisted scribe for joining Al and steel toward high-volume production. The task flow and schedule are appropriate as proposed. Other test modalities (cross-tensile, shear, even formability limit curves) may be added later based on progress and needs. The reviewer asked what the exact technological barriers are. This was not exactly clear other than the obvious need to increase welding speed for mass production.

Reviewer 5:

While the project work has not yet started, the approach still seemed somewhat vague to this reviewer. It would seem that at least some guidance on desired material combinations and configurations would have been included in the proposal (although they clearly could change) and not waiting for the project to start.

Additionally, when a reviewer asked about the potential to evaluate tailor welding as part of the project, the presenter stated this was not currently part of the plan, yet on the "critical assumptions and issues" slide, the issue of evaluating formability of the dissimilar joint is identified. It seems unlikely that a formability evaluation will be conducted on lap welded blanks. If so, then this should be clarified. Conversely, if the plan is indeed to use a butt welded joint (typical of tailor welded blanks), then it is not clear to this reviewer that the friction assisted stir scribe process has been evaluated (or is suitable) for this type of weld.

Finally, no OEM has been identified to guide in demonstration part (assembly) selection and to provide a die set for the demo part as mentioned on Slide 22.

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

Reviewer 1:

Although the project has not yet started, the stated plans to address weld speed and tool life increases appeared well informed and focused to this reviewer.

Reviewer 2:

The reviewer stated that this project had not started as of the date of the VTO AMR and there should have been an evaluation criterion of "Not Applicable." There are no accomplishments or progress to evaluate and the presentation stated this. The data presented are for previous work. For a one-year project that optimizes an existing technology, the technical accomplishments within the scope of the development should be easily met with minimum risk and no significant technical challenges. Two milestones are defined (four months apart) and a final deliverable is specified—so any future progress should be achievable.

Reviewer 3:

This reviewer commented that no milestones have been missed because the project has not yet started.

Reviewer 4:

The reviewer pointed out this is a new project.

Reviewer 5:

The reviewer said the project has not started; so, no accomplishments are expected or have been reported.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer indicated that it is excellent to see National Laboratories working closely with experienced Tier 1 industry partners on the practical application challenges related to a lab scale technique.

Reviewer 2:

The reviewer noted that the collaboration is between a DOE National Laboratory and a Tier 1 supplier of the FAST technology. The project basically optimizes the existing technology within a 1-year period and should be directly transitioned to the Tier 1 supplier at the end of this period.

Reviewer 3:
The reviewer stated that it is a great, if small, team, and suggested that it may be good to bring a Tier 1 in.

Reviewer 4:
The reviewer reported that this is a collaboration between PNNL and TWB.

Reviewer 5:
While there appears to be defined collaborative roles for TWB, the reviewer pointed out that those roles (and those of PNNL) do not appear to include the formability tests described on the "Critical Assumptions and Issues" slide (Slide 22). Additionally, this same slide mentions the potential need for an OEM partner that has not been identified anywhere else in the presentation. The collaborative roles for TWB and any additional partner need to be clearly defined very soon if this project is to have any chance at success.

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

Reviewer 1:
The reviewer described the plan as solid and remarked that this is an important problem and good approach.

Reviewer 2:
This reviewer observed no future research presented for this project because it had not started. The future research is what is planned to execute the one-year effort. The approach is excellent; future research should be excellent also.

Reviewer 3:
This reviewer remarked that moving toward 1500 MPa steel (not shown in the presentation) is a good prospect for door frames, etc. Nuggetting of the scribe tool is an issue, and there may be Stelite coatings or refractory materials that are better suited to handle the temperatures. The reviewer highlighted mention of conducting a formability study in the appendix, which sounds like a necessary step for industrial viability, along with corrosion studies (not mentioned).

Reviewer 4:
This reviewer noted that while the project is planned in a logical manner and decision points are defined, there are no comments at all regarding barriers and risk mitigation.

Reviewer 5:
This reviewer stated that baseline targets for weld performance are to be established, but should weld performance degradation be encountered, it is not clear what alternate paths would be investigated.

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

Reviewer 1:
This reviewer said the joining technology for this project is directly applicable to meeting the DOE VTO objective of joining dissimilar materials for construction of lightweight components and assemblies in automobiles.

Reviewer 2:
The reviewer asserted that joining Al and steel is critical and this is a very promising technology.

Reviewer 3:
This reviewer indicated that this project meets the lightweighting objectives of DOE.

Reviewer 4:

The reviewer explained that the project addresses improved welding speed and improved tool life to support high volume manufacturing needs to support implementation of dissimilar metal joints of Al to high-strength steels, which are clearly in support of the overall DOE objectives.

Reviewer 5:

The reviewer commented that the project addresses the main hindrance to wider industry acceptance of FSW as a vehicle light weighting and fuel saving technique. Tool changes need to reduce and weld speed needs to increase for FSW methods to be adopted.

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

Reviewer 1:

This reviewer noted that the project is $300,000 for one year and two performers, with an approximate 50% cost share from industry. For the period of performance and the number of entities involved to improve an existing technology, the resources are adequate.

Reviewer 2:

The reviewer explained that this is a reasonable budgetary plan—it is a small budget as some programs go, but sufficient for the targeted objectives.

Reviewer 3:

This reviewer observed sufficient resources for stated objectives, and expressed interest in seeing this type of work expanded in the future.

Reviewer 4:

The reviewer stated no comments or concerns.

Reviewer 5:

Given that material combinations and configurations and tools source have not been identified yet, the reviewer remarked that project timing and resources appear insufficient to achieve stated milestones and goals, especially with respect to formability tests and evaluation, and subcomponent production and evaluation.

Presentation Number: mat157
Presentation Title: Graphene-Based Solid Lubricant for Automotive Applications
Principal Investigator: Anirudha Sumant (Argonne National Laboratory)

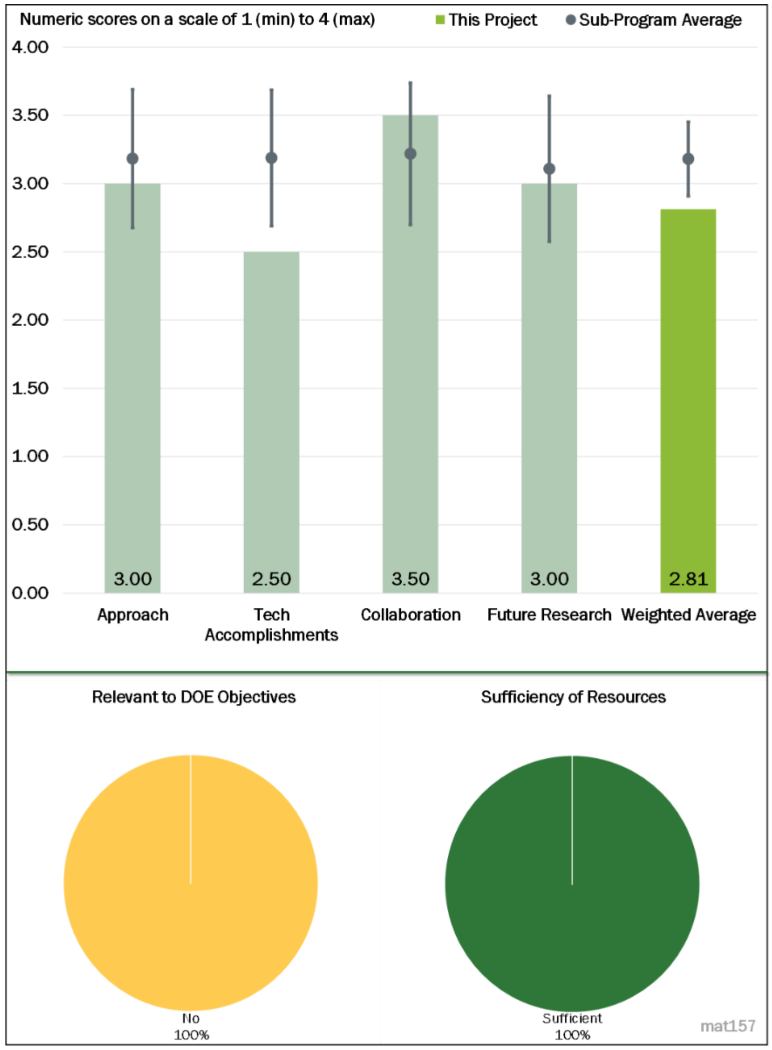

Figure 6-27 – Presentation Number: mat157 Presentation Title: Graphene-Based Solid Lubricant for Automotive Applications Principal Investigator: Anirudha Sumant (Argonne National Laboratory)

Presenter

Anirudha Sumant, Argonne National Laboratory

Reviewer Sample Size

A total of one reviewer evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the work so far is in lab scale, in which a new product is being evaluated using a standard test procedure. However, the testing needs to be compared with the currently used lubricants. The reviewer inquired about what the wear reduction is if current lubricants are used; and what the maximum temperature is in which current lubricants are tested for stability. Comparing the new product to the existing product was recommended by this reviewer. The reviewer also stated that the claim of reducing fuel consumption by reducing friction in the forming tool may be a stretch. If the parts can be produced easily, the cost is reduced and it may be an enabling tool only. The reviewer asked how much contribution is estimated for the increased productivity, and indicated that this needs to be quantified.

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

Reviewer 1:

The reviewer described this as a lab scale experimental project with accomplishments that are in line with expectations. However, the tests need to use standard product to compare the current state of technology to the proposed new product. The results indicate the reduction in friction is much lower for Al-Fe couple compared to the Fe-Fe couple. The reviewer asked what the major contributor is to this reduction.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that both industry and academic researchers are involved in the project. The presenter indicated that the industry partner was involved in framing the initial project. The interaction between the team is adequate.

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:

This reviewer said that the proposal for the next FY, for scaling up to expand the lubrication to a larger surface area, is good. The team has acquired a test set up for this purpose. Also, new tests are being proposed to evaluate the product. It is necessary to test the current lubricant using the same variables.

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

Reviewer 1:

The reviewer stated that metal parts are regularly produced using stamping process. Most of the products are steel based now. Non-ferrous materials such as Al and Mg are slowly replacing the steel products. During metal forming the material experiences friction and this reduces the efficiency of the process and slows it down. The new product is aimed to reduce this friction and improve the productivity. This is only an enabler and the cost is a major factor in the use of non-ferrous materials. The reviewer asked how much the cost will be reduced by marginally improving the productivity.

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

No comments were received in response to this question.

Presentation Number: mat159
Presentation Title: Powertrain Core Program: High-Temperature Lightweight Alloys–Aluminum-/Titanium-Based Alloys
Principal Investigator: Allen Haynes (Oak Ridge National Laboratory)

Presenter

Amit Shyam, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

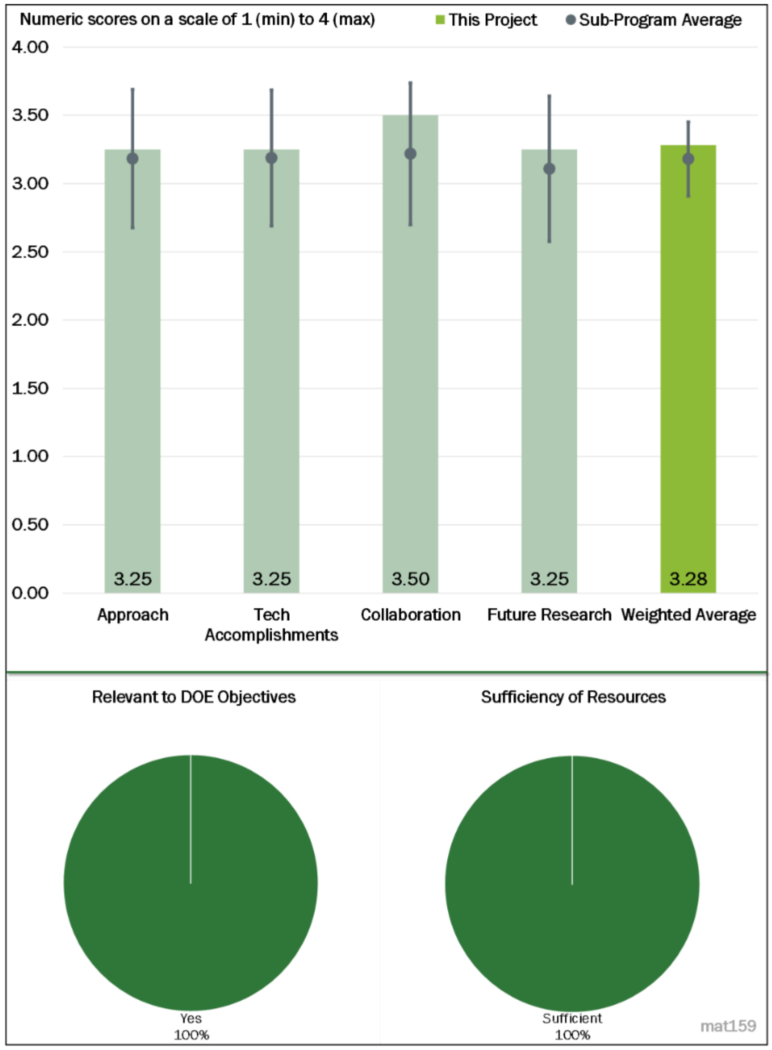

Figure 6-28 – Presentation Number: mat159 Presentation Title: Powertrain Core Program: High-Temperature Lightweight Alloys–Aluminum-/Titanium-Based Alloys Principal Investigator: Allen Haynes (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer described this project as well thought out.

Reviewer 2:

The reviewer stated that the team has done a good job charactering the θ’ phase (AlCu) and the interface with Al.

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

Reviewer 1:

This reviewer said the team has done a good job looking at the copper manganese zirconium system. It would be interesting to see the creep/fatigue behavior of the material due to the high temperatures that we are discussing (more than 400°C).

Reviewer 2:

The reviewer said the project team has done a nice combination of in situ microscopy with calculations and predictions

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer stated that there is good communication with the different labs involved. It would be nice to reach out to a primary Al ingot supplier to determine the cost of the material.

Reviewer 2:

This reviewer said it will be interesting to see if CRADA's form in near future

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

Reviewer 1:
This reviewer said it would be interesting to determine the series of phases that transforms before the θ' phase.

Reviewer 2:
This reviewer asked if sufficient focus is being applied to corrosion.

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

Reviewer 1:
The reviewer said this project supports lightweight, high temperature powertrain alloys, and the electrification of the engine with drive mass reduction in future vehicles.

Reviewer 2:
This reviewer stated that lightweight components are directly linked to a low CO_2 pathway.

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

Reviewer 1:
This reviewer said this is a good use of resources given to ORNL.

Reviewer 2:
The reviewer observed sufficient resources if carefully managed around many areas.

Presentation Number: mat160
Presentation Title: Powertrain Core Program: Higher Temperature (>550°C) Alloys–Nickel-/Iron-Based Alloys
Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

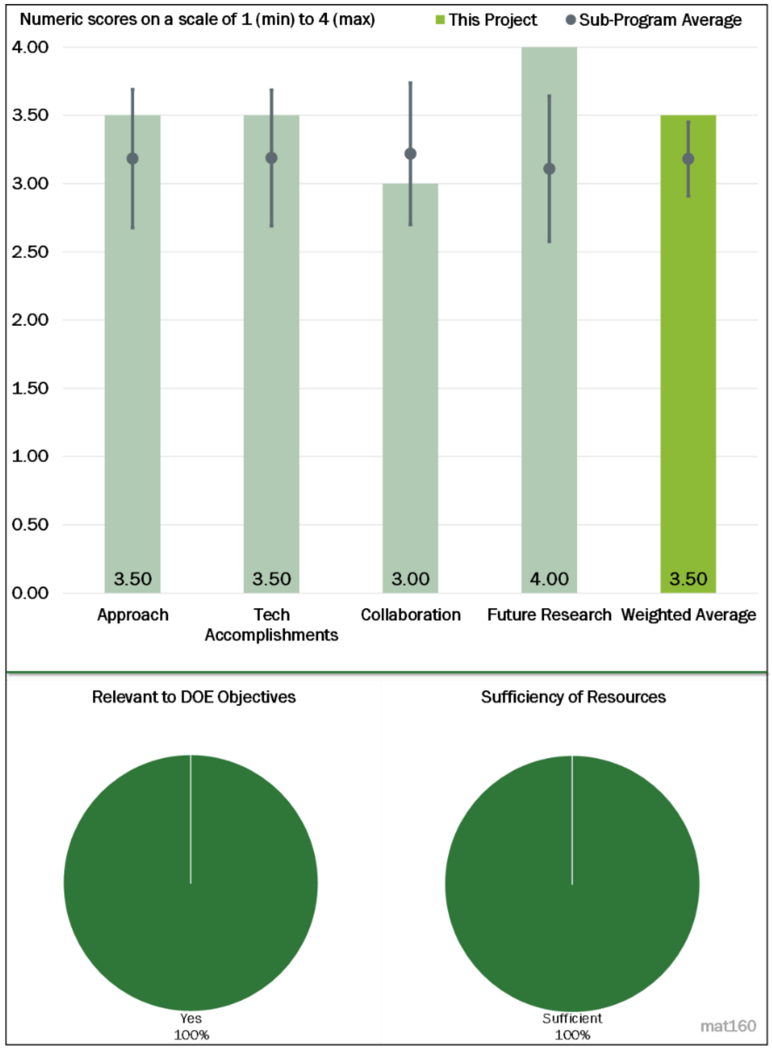

Figure 6-29 – Presentation Number: mat160 Presentation Title: Powertrain Core Program: Higher Temperature (>550°C) Alloys–Nickel-/Iron-Based Alloys Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

Presenter

G. Muralidharan, Oak Ridge National Laboratory

Reviewer Sample Size

A total of one reviewer evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this is a good approach, but almost double the work considering both chroma formers and the alumina former systems.

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

Reviewer 1:

The reviewer said this project has done a good job charactering the slow growing oxide scale on the alumina formers, which loses strength.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said the team has done a good job with communication/collaboration between the different labs.

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

Reviewer 1:

The reviewer remarked that the team has been very good about keeping the overall cost objective in mind when asked about adding rare-earth elements (Hafnium, etc.) like aerospace alloy development companies.

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

Reviewer 1:

The reviewer stated that high temperature/efficient powertrain engines will allow further lightweighting abilities.

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 PI did a good job with the resources at ORNL.

Presentation Number: mat162
Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys
Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Presenter

Dongwon Shin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

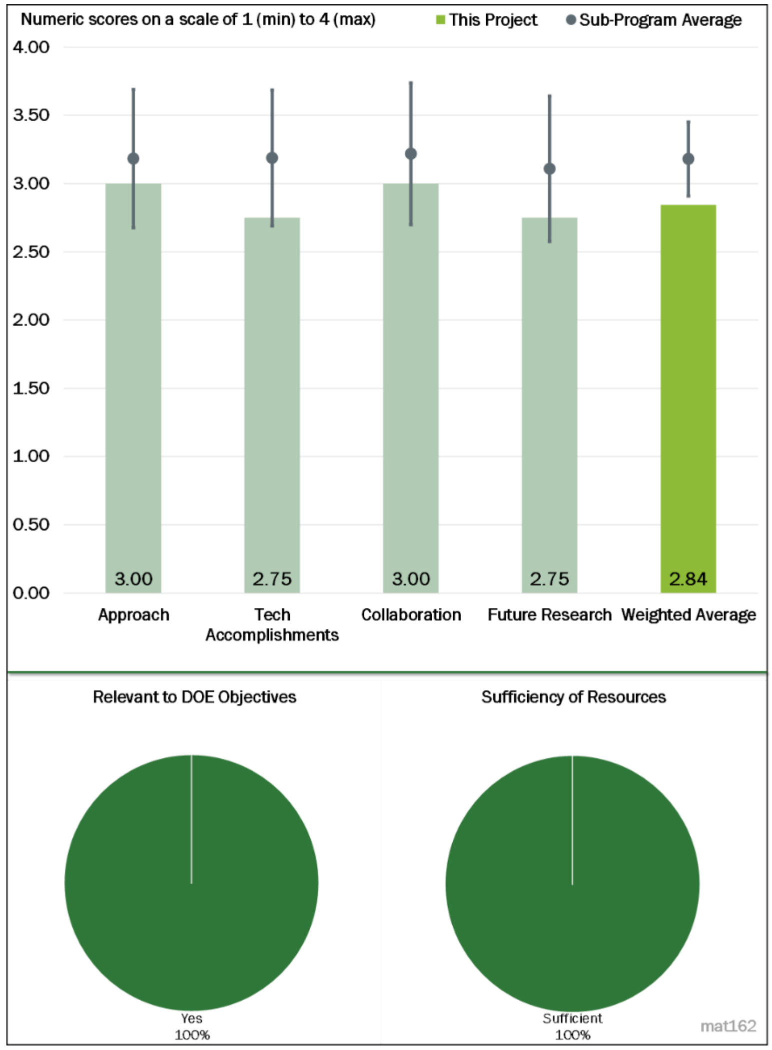

Figure 6-30 – Presentation Number: mat162 Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Reviewer 1:

The reviewer said there are no first principles models to describe oxidation-resistant multi-component alloys nor is there fundamental experimental data. The approach to leverage high performance computing resources and existing ORNL data on oxidation is valuable as it takes advantage of these unique capabilities and resources. The workflow is comprehensive and covers the appropriate material groups.

Reviewer 2:

The approach was not very clear to this reviewer. The team said it will use existing corrosion data (presumably showing weight gain over time, as shown in the slides), CALPHAD (which predicts phases at thermal equilibrium without kinetics), and MD calculations of fundamental properties to train a machine learning model using key characteristics. The reviewer explained that machine learning has to be given the same sort of data to learn from, and it needs lots of data; somehow the experiments, CALPHAD, and MD all have to give the same result for the algorithm. The reviewer asked how these will be done. The reviewer assumed that the MD will give inputs to the CALPHAD to somehow predict weight gain over time, but it was not clearly shown how that will be done.

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

Reviewer 1:

The reviewer said that the team has already developed some successful preliminary results for predicting the rate constant that picks up the appropriate trends, although more data are needed. The team is on the right track with creating models that can pick up on the correct trends to assist alloy designers in moving their materials forward for these applications. Because ORNL is using its own data sets and is confident in their source and consistency the use of machine learning will be appropriate in this case.

Reviewer 2:

This reviewer noted that there was no real progress, timeline, or task list shown. Some preliminary machine learning was shown, presumably from data, but nothing was shown with CALPHAD or MD.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said the team has developed good collaboration with the right partners, including a powertrain industry partner, which will be very important to provide perspective. The team is showing a good balance of tasks among the partners based on their particular expertise.

Reviewer 2:

The reviewer said the proposed collaboration seems reasonable, though it was not clear how everyone's data will be connected and eventually used with machine learning.

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

Reviewer 1:

The reviewer said the proposed future work is logical and focused on accomplishing the major goals with clear assignments for who does what. The project team has done a very good job in making the future work clear.

Reviewer 2:

This reviewer said there was not a clear, specific plan for future work. The reviewer asked what the tasks are, when they will be carried out, and what the work schedule is.

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

Reviewer 1:

The reviewer said this project is relevant to DOE VTO goals for efficiency, because the increased in-cylinder temperatures required for higher engine efficiency will require new understanding of how materials perform in these high temperature environments and how to make the materials more robust in this environment. Without these materials it will not be possible to reach engine efficiency targets.

Reviewer 2:

This reviewer said that using machine learning to train a corrosion model could be a powerful approach.

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

Reviewer 1:

The reviewer stated that the resources should be sufficient for work to be completed as described.

Reviewer 2:

This reviewer said the resources seem fine.

Presentation Number: mat163
Presentation Title: Multi-Scale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components
Principal Investigator: Mei Li (Ford)

Presenter

Mei Li, Ford

Reviewer Sample Size

A total of three reviewers evaluated this project.

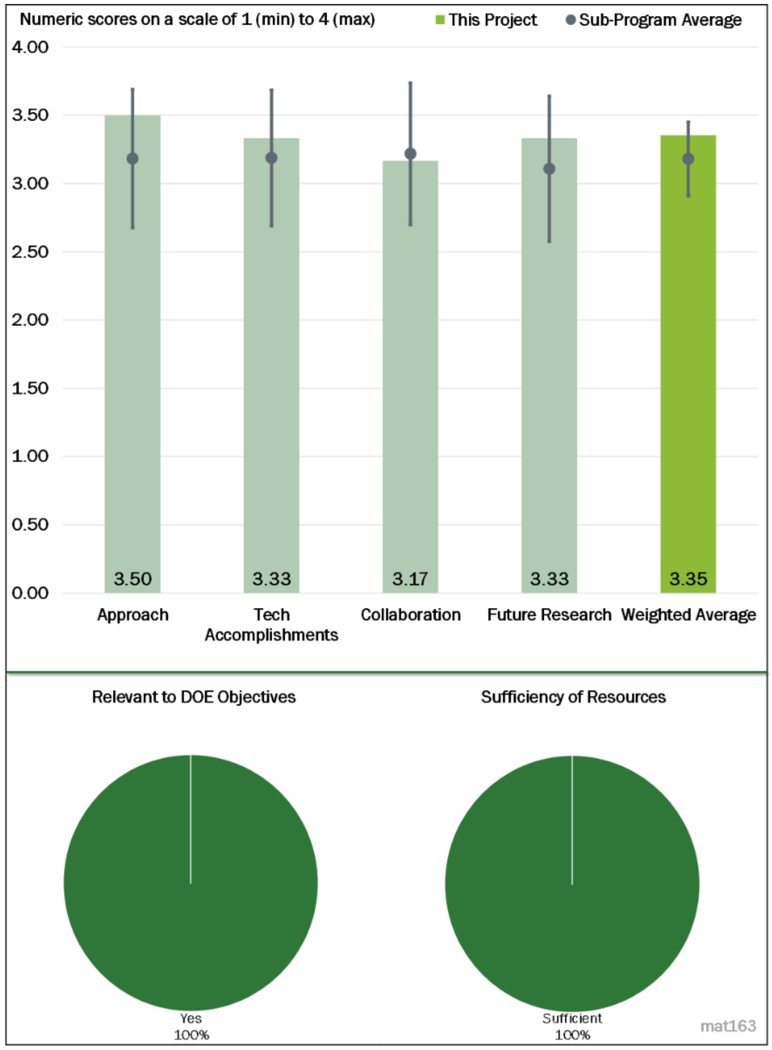

Figure 6-31 – Presentation Number: mat163 Presentation Title: Multi-Scale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components Principal Investigator: Mei Li (Ford)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer said the approach to develop a multiscale model for oxidation and its impact on thermomechanical fatigue performance is excellent. Corrosion/oxidation modeling is very challenging to model. The combined model development and experimental validation of model all the way up to the effect of oxidation life on the thermomechanical fatigue life prediction makes this a compelling project approach.

Reviewer 2:

The reviewer stated that this project's approach is designed to understand the failure mechanisms for exhaust manifolds and the key parameters to model these failures with experimental testing to determine these parameters. It represents a logical progression from fundamental experimental understanding to predictive modeling, which is a good approach. The modeling portion of the project builds on some existing foundational work and is looking properly at fundamental corrosion mechanisms to understand these phenomena in greater detail.

Reviewer 3:

This reviewer said the work being performed is very important to understanding the possible development of lower cost, lighter weight alloys for exhaust manifolds. As the temperatures increase the corrosion increases with the exhaust gases, air, and water. The modeling and experimental validation will help allow great insight at higher temperatures.

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

Reviewer 1:

The reviewer said given that the project is just in its first year of work, the accomplishments are very good. The team has already conducted validation of key parameters using experimental data with the potentially surprising result that oxidation did not change thermomechanical fatigue life in dry air. The team has been looking at the most important phenomena for the relevant high silicon molybdenum cast Fe alloy to predict the life of the cast Fe material as a means to develop the framework for more complex cast steel phenomena understanding. The team is well on its way to completing these tasks.

Reviewer 2:

This reviewer said the project is a new start this FY, and given the short period of performance the accomplishments reported are excellent. Multiscale models are being constructed with multiple techniques at different scales.

Reviewer 3:

The reviewer noted that the project has shown good progress during the six-month period since the project start. The project is on track and collecting good experimental data of corrosion of internal and external surfaces. The experimental design has been established and work has begun on testing materials under the experimental design conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said that the collaboration is excellent, with the project led by industry with university and National Laboratory partners.

Reviewer 2:

This reviewer said that although it was not discussed at any length in the presentation, the team does have a good set of experts at academia and the National Laboratories, along with the industry partner leading the effort. The team appears to have the right expertise to complete the work.

Reviewer 3:

The reviewer said the team did show some collaboration, but it was not clear on who was doing what during the presentation. It would be good to show a table explaining the team responsibility with the research.

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

Reviewer 1:

The reviewer said that the plan for future research—especially development of a model that takes into account oxidation and its effect on thermomechanical fatigue—differentiates this effort. Also, the experimental validation and uncertainty targets are compelling.

Reviewer 2:

This reviewer stated that the team's plans for the future work appear to be reasonable, and build up the expertise logically from experiment to modeling and progressing from simple to more complex material modeling. The list of future tasks and associated schedules are reasonable for completing the work as outlined.

Reviewer 3:
The reviewer noted that the project is in the beginning stages and the proposed future work looks to be appropriate.

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

Reviewer 1:
This reviewer said that exploration of failure mechanisms for high-temperature components such as exhaust manifolds will be very relevant to DOE objectives, as higher efficiency engines will operate at higher temperatures, resulting in additional component material failures if no measures are taken.

Reviewer 2:
The reviewer said the increase in exhaust temperature is driving the demand for the development of a comprehensive understanding of oxidation and oxidation plus fatigue. The efforts in this project take us in that direction.

Reviewer 3:
This reviewer pointed out that the exhaust manifold is a heavy item on the vehicle due to the high temperature the material is subjected to in a corrosive and oxidative environment. In order to reduce the mass, the material sets need to be better understood so that new materials may be investigated that allow for the production of thinner parts due to improved corrosion resistance.

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

Reviewer 1:
The reviewer remarked that the objectives are clearly articulated with a good Gantt chart showing the work to be completed with milestones. The work is sufficiently funded for the level of effort shown.

Reviewer 2:
The reviewer said the resources available to the project appear to be sufficient to achieve the project goals in a timely and useful fashion.

Reviewer 3:
This reviewer said the project resources are appropriate given the size of this effort.

Presentation Number: mat164
Presentation Title: Multi-Scale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials
Principal Investigator: Michael Tonks (University of Florida)

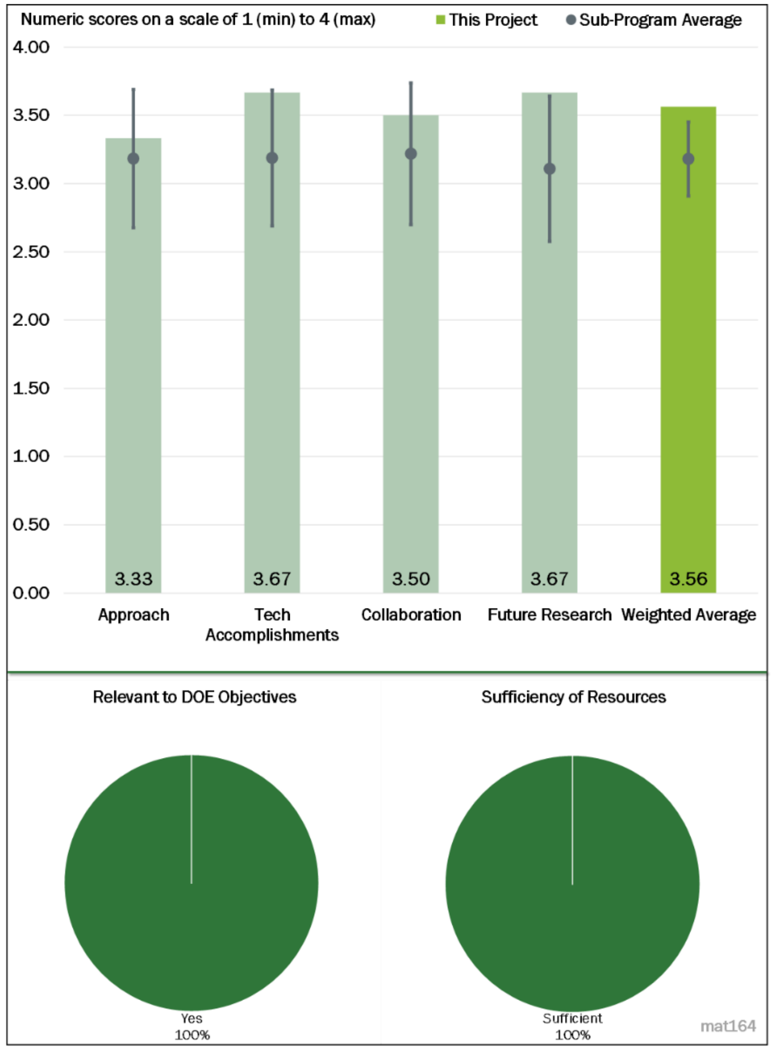

Figure 6-32 – Presentation Number: mat164 Presentation Title: Multi-Scale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials Principal Investigator: Michael Tonks (University of Florida)

Presenter

Michael Tonks, University of Florida

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the approach is well thought out with a well-established work plan. The presentation clearly articulates the responsibility of each partner.

Reviewer 2:

The reviewer noted that this is a relatively new start project. The approach is very well designed for a modeling effort that starts with atomistic simulations of basic materials and evolves through mesoscale modeling of the valve material and validated with experimental data from engine tests and materials characterization. Data from the literature and from an engine manufacturer to validate the end-state model is a sound approach that covers all levels of data required for a successful model.

Reviewer 3:

The reviewer said this project has a good balance between experiments and theory. Experimental components aim to collect fundamental data for relevant materials, and the modeling parts aims to integrate different tools, i.e., the phase field model and semi-empirical corrosion model. While the project aims to tackle highly-relevant and practical commercial alloys, it is questionable whether the proposed modeling approaches can efficiently handle those complex multi-component systems. As an example, the reviewer asked whether mobilities for all the elements are needed for phase field model readily available in the literature, and whether it is okay to assume that oxide scale growth of valve steel alloys will only follow Wagner-type oxidation behavior.

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

Reviewer 1:

The reviewer stated that the team has made impressive progress within only six months in three different areas of the project.

Reviewer 2:

This reviewer noted that the first six months of the project have shown good progress with an experimental design and setup established, and a modeling framework started with literature review data for the modeling efforts.

Reviewer 3:

The reviewer observed that the project is divided into three areas and technical progress was made in the short time since the project began. A unique corrosion apparatus was designed and this reviewer has some concern that the results obtained using this apparatus may not compare with standard test methods used by industry. The project has completed review of corrosion models found in the open literature and a phase field stainless steel corrosion model has been formulated. Data from the literature have been used to fit a semi-empirical macroscale corrosion model. This is significant progress for the first few months of effort.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer said the collaboration is between a university, a DOE National Laboratory, and an engine manufacturer encompasses all entities needed to develop and transition an effective corrosion model for a specific material. Based on the approach and schedule presented, there appears to be good coordination for the initial efforts of the project.

Reviewer 2:

The reviewer noted that the participants of this project are from the university, a National Laboratory, and industry—a great balance.

Reviewer 3:

The reviewer said the presentation showed good team work between the team members, with their roles clearly defined. There could be a better explanation on how the PI coordinates the activities the team members being in different locations across the country.

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

Reviewer 1:

The reviewer said that because this is a relatively new start project, the proposed future research is the execution of the remaining tasks defined in the approach and project schedule. Because the project appears to be well planned in a logical manner for developing these computational tools, there should be minimum risks for completing the project to develop a successful corrosion model within the given resources and performing agencies.

Reviewer 2:

This reviewer stated that the proposed work appears to be sound. However, it would be critical to collect/populate reliable input parameters to be used within INL's MOOSE. It will be ideal if experiments can be used to calibrate those simulation parameters.

Reviewer 3:
The reviewer said the presentation clearly stated what the path forward is.

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

Reviewer 1:
The reviewer said the project directly supports of DOE VTO propulsion materials objectives to have computational tools for predicting the performance of engine components in high temperature corrosive environments and will be a baseline tool as the operating environments become more aggressive in the future.

Reviewer 2:
The reviewer said the proposed research tasks are highly relevant to DOE objectives, particularly DOE EERE VTO.

Reviewer 3:
This reviewer stated that as combustions temperatures increase with high compression engines, improved material performance is necessary. This project helps DOE achieve the goal of more fuel-efficient engine systems.

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

Reviewer 1:
This reviewer noted that the project funding is $1.5 million over 3 years, or $500,000 per year for the principle performer and two collaborators. Because this project involves modeling over the entire physical spectrum from the atomistic to the macroscale, with a university doing the majority of development, the funding and facilities are considered reasonable and adequate for the execution of the project.

Reviewer 2:
This reviewer stated that the team proposed the appropriate amount of work for the allocated budget. The reviewer asked whether the cost-share from the industry partner is missing or absent.

Reviewer 3:
The reviewer said the project is sufficiently funded and the team has laid out a good plan to show progress. However, there is not a good explanation of the milestones on the chart or in table form.

Presentation Number: mat165
Presentation Title: Direct-Extruded High-Conductivity Copper for Electric Machines
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

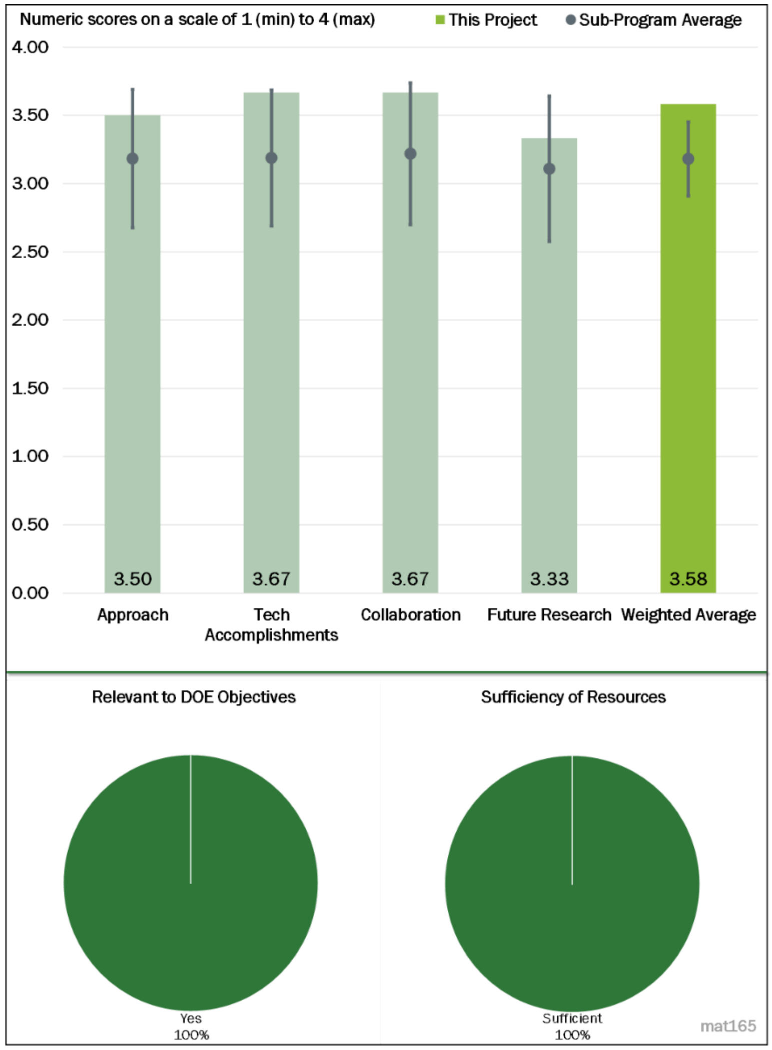

Figure 6-33 – Presentation Number: mat165 Presentation Title: Direct-Extruded High-Conductivity Copper for Electric Machines
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Presenter
Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said the work is well-focused and if successful, would make a substantial contribution to the overall efficiency of electric machines (and other types of electrical hardware such as circuitry). The group appears to have found a reliable method of measuring conductivity (a key challenge in this field) and that, in itself, is a key contribution. The remaining tasks of fabricating actual wire and then a rotor component that can be tested are still at an early stage so there is not much upon which to comment. The next phase of this work will thus be crucial in determining the overall value of this work.

Reviewer 2:
This reviewer stated that the approach is to develop higher conductivity copper composite by application of ShAPE solid state processing. Various forms of carbon are tried as copper already has very high thermal conductivity. The overall scientific approach and project plan are excellent.

Reviewer 3:
The reviewer said this project is well designed, and the approach will lead to addressing, if not overcoming, the barriers to getting this technology to market. The reviewer noted that the presentation did not give any sense of how many milestones there are in total. Only the milestones that have been met were listed. Please list all milestones—both completed and in progress—during the next review exercise.

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

Reviewer 1:
The reviewer said the project team has made excellent progress on a very challenging technical problem. Also, the presentation covering the technical challenges and the progress made to date was excellent.

Reviewer 2:
This reviewer stated that a great deal of work has been carried out. Four Milestones have been reached, including the development of a composite material that shows higher conductivity than copper. The mechanical tests comparing this copper-based composite material with pure copper also showed promising results. It will be prudent to determine the optimum graphene concentration that would yield the best conductivity of the copper composite.

Reviewer 3:
The reviewer said this project has overcome a key barrier in finding a method of measuring conductivity, but the real "proof of the pudding" will come once components are made and tested—and it is too early to determine how that phase will go. Similarly, the issues of mechanical properties and production cost will emerge as core to the feasibility of commercial adoption of the technology—and it is too early to comment with any certainty on those issues. In short, the next evaluation of this project should yield some very important information.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer stated that based on the give-and-take during the question period, it appears that the coordination and collaboration within the project team is very deep and worthwhile.

Reviewer 2:
The reviewer noted that the project is being executed in partnership with GM. The size, resources, experience, and market share that GM possesses makes this partnership a strong one.

Reviewer 3:
This reviewer said there is good collaboration between a National Laboratory, industry (GM), and additional university partners.

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

Reviewer 1:
The reviewer said the proposed future work is logical and sequential, and will assist in reaching the goals of this project. The PIs should consider cost and high throughput analyses for economic viability of the material being developed.

Reviewer 2:
This reviewer said the use of different grades of graphene and component level scaling are appropriate steps to demonstrate the viability of this technology.

Reviewer 3:
This reviewer said that as noted, the key issues that will eventually emerge will be cost, durability, and manufacturability. While it is too early at-present to comment on these, it will be important that they be considered by the project team in the coming phase of the project.

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

Reviewer 1:
The reviewer noted that the efficiency of electric machinery is intimately connected to the conductivity of the electrical materials used within them. This project is focused on that issue and so, it is definitely in support of DOE objectives to enhance the performance of EVs.

Reviewer 2:
This reviewer said the project is relevant to the development of a higher density electric motors that could increase the driving range of an electric vehicle. It could also result in weight savings if smaller motors can be built that produce the same amount of power (compared with a larger and heavier one) to drive the car. This relates directly to lightweighting of vehicles resulting in better energy efficiency.

Reviewer 3:
The reviewer stated that increasing the performance and reliability of electric machines is relevant for multiple propulsion systems.

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

Reviewer 1:
The reviewer said the resources are sufficient to finish this project and transfer technology to industry.

Reviewer 2:
This reviewer said that there do not appear to be any difficulties on the resource side of this project at-present, but the work on durability and manufacturability may require additional resources once those issues come into focus.

Reviewer 3:
The reviewer stated that the resources seem sufficient. However, it is difficult to tell because of the presentation did not indicate how much money is left to be spent.

Acronyms and Abbreviations

°C	Degrees Celsius
3-D	Three-dimensional
Al	Aluminum
AMR	Annual Merit Review
Bio-ACN	Bio-acrylonitrile
CAE	Computer-aided engineering
CALPHAD	CALculation of PHAse Diagrams
CF	Carbon fiber
CFD	Computational fluid dynamics
CFRP	Carbon fiber-reinforced polymer
CPEC	Close proximity electromagnetic carbonization
CpK	Process capability index
CTE	Coefficient of thermal expansion
CTP	Coal tar pitch
CuCl	Copper chloride
DFT	Density functional theory
DIE	Digital image correlation
DOE	U.S. Department of Energy
FAST	Friction stir assisted scribe technology
FDS	Flow drill screw
FEM	Finite element analysis
FSW	Friction stir welding
GI-XRD	Glancing incidence X-ray diffusion
GPa	Gigapascal
HD	Heavy duty
HP-RTM	High-pressure resin transfer molding
ICME	Integrated computational materials engineering

ILSS	Interlaminar shear strength
LCCF	Low cost carbon fiber
LD	Light duty
LTC	Low-temperature carbonization
MD	Molecular dynamics
Mg	Magnesium
MMC	Metal-matrix composites
NCF	Non-crimp fabrics
NDE	Non-destructive evaluation
NVH	Noise, vibration, and harshness
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PAN	Polyacrylonitrile
PBO	Polybenzoxazole (thermoplastic)
PBT	Polybutylene terephthalate (thermoplastic)
PE	Polyethylene
PP	Petroleum pitch
RSR	Resistance spot rivet
ShAPE™	Shear Assisted Processing and Extrusion
SHPB	Split Hopkinson pressure bar
SiMo	Silicon-Molybdenum
SPR	Self-pierce rivet
Tg	Glass transition temperature
TiB_2	Titanium diboride
TMAC	Test Machine for Automotive Crashworthiness (at ORNL)
Tv	Vitrimer transition temperature
USW	Ultrasonic welding
UD	Unidirectional (carbon fiber)

UHMWPE	Ultrahigh molecular weight polyethylene
UV	Ultraviolet
VTO	Vehicle Technologies Office