annual progress report

HEAVY VEHICLE SYSTEMS OPTIMIZATION MERIT REVIEW AND PEER EVALUATION

FREEDOMCAR AND VEHICLE TECHNOLOGIES PROGRAM

Less dependence on foreign oil today, and transition to a petroleum-free, emissions-free vehicle tomorrow.

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Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

FreedomCAR & Fuel Partnership

21st CENTURY TRUCK PARTNERSHIP

Department of Energy

Washington, DC 20585

Dear Colleague:

This document summarizes the comments provided by the Review Panel for the FY 2006 Department of Energy (DOE) Heavy Vehicle Systems Optimization Peer Review Meeting, held April 18-20, 2006 at Argonne National Laboratory in suburban Chicago, Illinois. The goal of this document is to provide the reader with a summary of the comments and scores from expert reviewers from industry and government on these systems optimization projects.

The format used in this report is similar to that used in the long-running Advanced Combustion and Emission Control Merit Review and Peer Evaluation for DOE National Laboratory Projects. Information is provided both on a quantitative basis (through project review scores) and a qualitative basis (through reviewer text comments) to outline reviewer opinions on these activities.

Thank you for participating in the FY 2006 DOE Heavy Vehicle Systems Optimization Peer Review Meeting. Please feel free to provide suggestions for improving this process in the future.

Tien Duong, Team Leader
Vehicle Systems Technologies
FreedomCAR and Vehicle Technologies Program

cc: Ed Wall
Connie Bezanson
Rogelio Sullivan
James Eberhardt
John Fairbanks
Steve Goguen
Roland Gravel
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Introduction

This report is a summary and analysis of comments from the Review Panel at the FY 2006 DOE Heavy Vehicle Systems Optimization Merit Review and Peer Evaluation, held April 18-20, 2006 at Argonne National Laboratory. The work evaluated in this document supports the FreedomCAR and Vehicle Technologies Program. The results of this merit review and peer evaluation are major inputs used by DOE in making its funding decisions for the upcoming fiscal year. The objectives of this meeting were to:

- Review and evaluate FY 2006 accomplishments for DOE programs in heavy vehicle systems optimization, including aerodynamic drag, friction & wear, innovative concepts, and thermal control.
- Provide an opportunity for program participants to offer suggestions on directions for the DOE-sponsored R&D program so that the highest priority technical barriers are addressed. The meeting also serves to facilitate technology transfer.

The Review Panel members, listed in Table 1, attended the meeting and provided comments on the projects presented. They are peer experts from a variety of related backgrounds, including industry, government, and academia. A complete list of the meeting participants is presented as an appendix.

Table 1: Review Panel Members

Member Name	Affiliation
Harold Dobbs	U.S. Army TACOM
Marty Fletcher	U.S. Xpress
John Foss	Michigan State University
Ken Goretta	U.S. Air Force
Ralph Hulseman	Michelin
Frank Kelley	Mercury Marine
Jorn Larsen-Basse	NIST (retired)
Ken Ludema	University of Michigan (retired)
Gene Olson	International Truck & Engine Corporation (retired)
Vic Suski	Shenandoah Express
Ken Visser	Clarkson University
Jonathan Wattelet	Modine Manufacturing
Jack Williams	Ford Motor Company (retired)

Analysis Method

As shown in Table 1, a total of thirteen advisory panel members participated in the merit review. A total of 27 project presentations and posters were reviewed at the meeting, and a total of 100 review sheets were received from the review panel members (not every panel member reviewed every project). To determine the scores for these projects, the projects were placed into four categories that were established in consultation with DOE program managers. These four categories were:

- Aerodynamic Drag
- Friction and Wear
- Innovative Concepts, and
- Thermal Control.

Review panel members were asked to provide numeric scores (on a scale of one to four, with four being the highest) for five aspects of the research on their review form, a sample of which can be found as an appendix to this report. The five aspects were:

- Relevance to overall DOE objectives;
- Approach to performing the research and development;
- Technical accomplishments and progress toward achieving the project and DOE goals;
- Technology transfer and collaborations with industries, universities, and other laboratories; and
- Approach to and relevance of proposed future research.

The numeric scores given to each project by the reviewers were averaged to provide the overall score for that project for each of the five criteria. An average score for the five criteria was also calculated within each of the four project categories for all projects in that category. In this manner, a project's overall score can be compared to other projects in that category.

Reviewers were also asked to provide qualitative comments on the five research aspects, as well as on the specific strengths and weaknesses of the project and any recommendations for additions or deletions to the work scope. These comments, along with the quantitative scores, were placed into a database for easy retrieval and analysis. These comments are summarized in the following sections, with an indication of how many reviewers provided written comments for that project and that question. All reviewers of a given project provided a numeric score for each of the five criteria, but did not necessarily provide qualitative comments.

Organization of the Report

This report is organized in four main sections, one section for each of the four main R&D categories. The first page of each section presents a summary of the average scores for the projects in that category, highlighting the highest scores for each of the five scoring aspects and the category average for those aspects. A brief description of the general type of research being performed in each category is also presented.

The remaining pages of each section present the results of the analysis for each of the projects discussed at the merit review. Graphs showing how the particular project compared with other projects in its category are presented, as well as a discussion of these results. A summary of the qualitative comments is also provided.

This category includes projects to examine ways to reduce aerodynamic drag of tractor-semitrailer combination trucks. The goal of this research is to reduce the drag coefficient of such trucks by 25%, resulting in an approximate increase in fuel economy of 12.5% at 65 miles per hour. Projects are using a combination of wind tunnel testing, computational tools, and on-road testing to develop and validate the performance of aerodynamic devices. This category contributes to the overall heavy vehicle systems optimization goal of increasing fuel efficiency by 25% through reductions in parasitic losses.

Below is a summary of average scores for 2006 for the seven projects in this category, along with the average, minimum, and maximum score for all projects in this report. The highest score in this category for each question is highlighted.

Summary of Scores for Projects in this Section

Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomp-lishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
4	*DOE's Effort to Reduce Truck Aerodynamic Drag through Joint Experiments & Computations*: Rose McCallen, Lawrence Livermore National Laboratory **	**4.00**	**4.00**	**3.50**	3.50	3.00	**3.60**
6	*Heavy Vehicle Drag Reduction Devices: Computational Evaluation & Design:* Kambiz Salari, Lawrence Livermore National Laboratory	2.71	2.86	2.43	2.57	2.43	2.60
10	*Heavy Vehicle Drag Estimation using Commercial CFD Tools:* David Pointer, Argonne National Laboratory	3.60	3.60	**3.50**	3.40	3.20	3.46
12	*Heavy Vehicle Drag Reduction: Experimental Evaluation & Design:* James Ross, National Aeronautics & Space Administration	3.43	3.57	3.14	3.71	2.83	3.34
14	*Truck Manufacturers Program to Reduce Aerodynamic Drag:* Robert Clarke, Truck Manufacturers Association	3.50	3.67	3.25	**3.75**	**3.50**	3.53
16	*Heavy Vehicle Drag and Safety: Spray from Rolling Tires (Poster):* Fred Browand, University of Southern California	3.50	4.00	3.25	2.67	3.00	3.28
18	*Heavy Vehicle Drag and Safety: Research and Development (Poster):* John Paschkewitz, Lawrence Livermore National Laboratory **	2.00	3.00	--	3.00	--	2.67
	Average Score for This Category	**3.30**	**3.48**	**3.07**	**3.24**	**2.92**	**3.20**

** = Projects with two or fewer reviewers.

Overall Program Scores

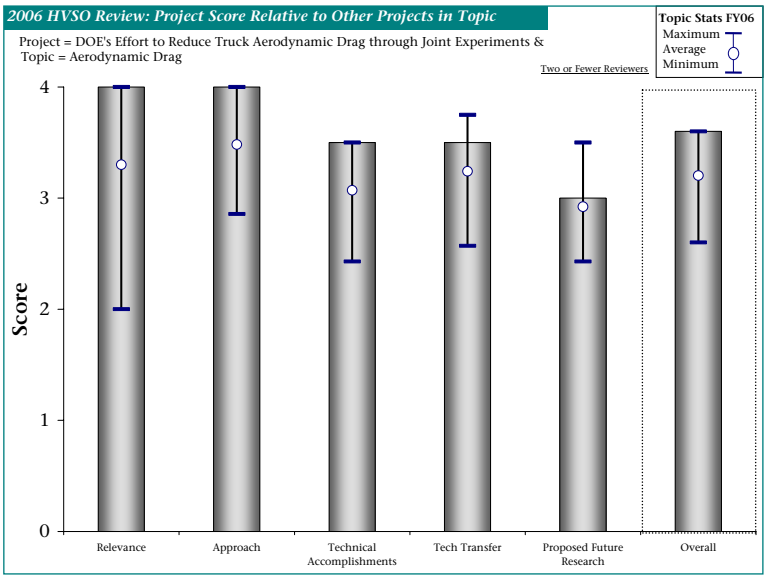
	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
Overall Program Average	3.52	3.51	3.25	3.27	3.24	3.36
Overall Program Maximum	4.00	4.00	4.00	4.00	4.00	4.00
Overall Program Minimum	2.00	2.67	2.33	2.00	2.43	2.60

Aerodynamic Drag

DOE's Effort to Reduce Truck Aerodynamic Drag through Joint Experiments & Computations: Rose McCallen, Lawrence Livermore National Laboratory

Brief Summary of Project

This project is the overview of the DOE Aerodynamic Consortium led by Lawrence Livermore National Laboratory, in collaboration with Argonne National Laboratory, Sandia National Laboratories, NASA, University of Southern California, Caltech, Georgia Tech Research Institute, University of Tennessee Chattanooga, and Auburn University. The goal of the overall consortium program is to reduce aerodynamic drag of heavy-duty vehicles by 25%, which would result in a 12% overall fuel savings (about 4.2 billion gallons per year total). The consortium is undertaking a mix of computational fluid dynamics analysis, wind tunnel testing, and track testing to identify and verify performance of drag reduction devices.



Question 1: Relevance to overall DOE Objectives (Written responses from 1 of 2 reviewers)

The commenting reviewer said that this is exactly the sort of program DOE should support: likely to produce near- and longer-term payoffs, which themselves are significant. This project has outstanding industry buy-in now and potential later. Without DOE support, much of what is being learned and accomplished simply could not happen.

Question 2: Approach to performing the research and development (Written responses from 1 of 2 reviewers)

The commenting reviewer thought some of the effort could be focused away from modeling and design into more practical and highly important considerations, such as component design, performance, and durability.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 1 of 2 reviewers)

This reviewer thought the project represented a fine effort in total. This reviewer agreed with others who commented that the auto manufacturers know a lot about aerodynamics, but the reviewer can't imagine they'd be willing to share the really good stuff and felt that, looking at the designs of their pick-up trucks, they are far from efficient behind the cab. Given the starting point, this work has progressed admirably. It clearly should move toward use of commercial codes.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 1 of 2 reviewers)

The reviewer thought the technology transfer was excellent in total, with clear goals of which other firms/sectors are invited to join.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 2 reviewers)

The reviewer would like to see some efforts shifted toward a nearer-term goal of getting OEMs to attach more devices. Component development and durability testing are required.

Specific Strengths and Weaknesses (Written responses from 2 of 2 reviewers)

- Specific Strengths
  - Outstanding synergism and identification of important goals. The team's sum total of capabilities is remarkable.
  - I specifically like the way you are approaching and directing the program. Your communication of the status was very clear and concise. Your openness to a variety of concepts and desire for industry input and cooperation is apparent. I believe the program is proceeding in the correct direction.
- Specific Weaknesses
  - I would prefer to see more aggressive targeting of some near-term wins.
  - Trailer OEM input and cooperation [is needed] as well as the end customer input.
  - Concepts presented are not new: need new ideas and concepts that will raise eyebrows.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 2 reviewers)

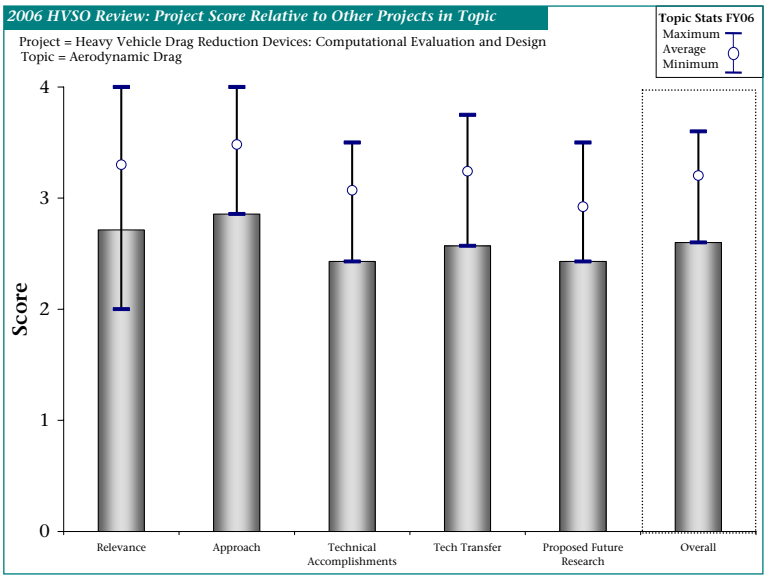
- Already discussed in terms of additions. I see nothing to cut. The drag reduction work is vital to this program and the program is vital to DOE and the USA. Outstanding work.
- Heavier push on the integrated tractor/trailer system.

Aerodynamic Drag

Heavy Vehicle Drag Reduction Devices: Computational Evaluation & Design: Kambiz Salari, Lawrence Livermore National Laboratory

Brief Summary of Project

In this project, the research team is using advanced computational fluid dynamics to analyze simple and complex geometrical representations of Class 8 highway tractor-semitrailer combination trucks in order to quantify the potential drag reduction impact of aerodynamic devices on these vehicles. This research team is using the advanced computing facilities at LLNL.



Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 7 reviewers)

Review comments on this aspect of the research were mixed. On the positive side, a reviewer thought the project meets the specific criteria called for in 21CTP. Another noted the clear focus on energy efficiency and aerodynamics. A third said that evaluation of new concepts and their effectiveness is key to the program. Coordination of CFD and experiment is also crucial. The stated goals are aligned with the program and this is a good strategy to evaluate concepts and guide experiments.

On the other hand, a reviewer said that this seems to be more of a "tool" (CFD) project rather than an aero project. The project work depends on the geometry of tractor, so if the tractor geometry changes, the work will have to start all over: a "never-ending project." A reviewer commented that this CFD project is very unlikely to make any contribution to overcoming the barriers and improving heavy vehicle fuel economy. It does not support and is not responsive to the overall DOE goals and objectives. Technical accomplishments against performance measurements were not presented and future research plans with CFD have little relevance to eliminating barriers and instilling confidence in the community. Because of the lack of correlation to experimental measurements, this reviewer found it hard to envision that these numerical procedures will add any value to the effort. A final reviewer had several specific comments: this reviewer can understand why the speaker considers his approach to be a relevant and rational approach, but disagrees with this assessment. The problems outlined by this reviewer are:

- The slides describing the accomplishments, the relationship between aerodynamic drag and fuel consumption, and the approaches to achieving drag reduction cannot be considered to be "new."
- A slide describing methods to ascertain critical flow features leads to an end-state (scaled heavy vehicle models) for which his numerics cannot mimic the experiments (it is understood that no numerics can do so).
- Slides on the guidelines for computational modeling explicitly show the numerical problems (relative to influences of computational methods on drag coefficient).
- A slide in the presentation claims credit for an accurate drag coefficient when it is apparent that this is a fortuitous result of compensating effects.
- Slides on drag reducing devices are reports of others' work. Hence, these are not included in "Relevance."
- His claimed "Flow Conditioning" on the aft face is, to this reviewer, fully unrealistic. The prime mover for this flow would be a centrifugal blower. The blower itself will be about 70% efficient. Its outlet area may be on the order of 0.075 square meters. This outflow kinetic energy will be "totally lost" as the flow area expands to some fraction of the aft face area. Further losses will occur to distribute the flow over a large area. There is an incredible naiveté in presenting such a result with "no losses."
- Gap flow: effect of the vehicle's yaw angle must be reported for a physically complete understanding.

Question 2: Approach to performing the research and development (Written responses from 7 of 7 reviewers)

As with Question 1, review comments were mixed. The involvement of end users is critical to determining the overall feasibility of potential technology, noted the first reviewer. Another said that there was a good connection of basic science to engineering to potential industrial use. A reviewer suggested that it is apparent the researchers know what they are doing, but they need work on communicating progress and results. Finally, a reviewer said the work was great for the narrow, very specialized kind of project it is.

On the other hand, this method development project as presented lacks focus (according to this reviewer) and will be unlikely to deliver any useful results. Trying to validate the various modeling strategies of numerous computer codes that will likely not be used does not support the goals of improving fuel economy. It is not responsive to project objectives. From the presentation, this CFD Modeling project has (apparently) made a major change in direction and now includes experimental, wind tunnel, and on-road work. (Reference FY2005 report, Project I.B.). The goals, achievements, technical approach, etc. are now quite different; very little was reported on computational modeling aspects of the project. Further, the experimental work is a significant overlap with other projects. Because the rationale for this major change in direction from earlier work was not discussed in the presentation, this reviewer was left with the conclusion that the project lacks discipline and focus, is too broad and vague, has no specific deliverables, and will not deliver any useful results.

This reviewer continued by saying that on the CFD modeling aspects of the work, very little information was presented. It appears that numerous CFD modeling codes/strategies are being examined, but this reviewer was unable to get a sense of the scope of the work or technical approach. The audience was not told how many computer codes, what were their names, were they commercial or in-house, the rationale for doing the evaluation, how the results would be used, by whom, etc. The variety of turbulence models, numerical procedures, meshing strategies, discretization schemes, boundary conditions, yaw angles, convergence, validation against experimental measurements, shape development results, etc. make this a "never-ending project." This reviewer did not see any benefits at all to the DOE objective.

A final reviewer said that it is not clear how (or even if) the CFD is used to evaluate the merits of drag reduction concepts. The associated uncertainty and error (grid resolution, incorrect physics, etc.) negate this. The focus appears to be on improving modeling techniques.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 7 reviewers)

Some positive comments were received on the technical accomplishments. One said that the list of achievements is evidence to the technical accomplishments. Another noted that the team had demonstrated greater than 25% drag reduction, that computational tools are advancing well, but that limitations to predict key areas remain. A gain within a very narrow way, said another reviewer.

On the other hand, a reviewer felt it was very difficult to understand the accomplishments and program direction. Concept evaluation strategy is good, said another reviewer, but there is a lack of any substantive CFD results to evaluate drag devices. The stated "Achievements" were not all elucidated. There was too much focus on modeling improvement issues, and not on usefulness to evaluate concepts, in this reviewer's viewpoint.

Finally, a reviewer said that the technical accomplishments against performance measurements were not presented and future research plans with CFD had little relevance to eliminating barriers. The presenter did not seem to know that several commercial codes are currently being used in the automotive industry (internationally). The numerical procedures have been validated and are widely used for aerodynamic design. They are routinely discussed at the SAE World Congress every year. Again, the presenter was not aware of this large body of work that would have been very helpful to this project.

This reviewer continued that the investigators predicted the correct drag coefficient number (accidentally) and thought this was a useful and validating result. However, the surface pressures and wake flow patterns were in serious disagreement with experimental measurements. This reviewer was surprised that the presenter thought this was acceptable and did not appreciate the concerns. Further, this reviewer did not understand the GTS wake correlation comparisons; it raised many unanswered questions in the reviewer's mind. Again, the presenter did not

explain.

Additionally, during the discussion, the reviewer observed that the presenter did not demonstrate an understanding of practical vehicle aerodynamics and cooling airflow. For example, no mention was made of the internal flow resistance simulation of the radiator+condenser+fan+shroud in the CFD model. This reviewer said that everyone knows that an internal airflow opening will increase drag; there is no need to conduct a CFD simulation to make this point. If the internal restrictions were not represented (at least approximately) then the simulation was totally unrealistic and the results of no value.

There was a lot of confusion (in this last reviewer's opinion) created with the percent drag coefficient improvements shown for the add-on devices from various wind tunnels. Because the baseline drag coefficient numbers and model details were not discussed, the chart generated much confusion in the audience. The presenter didn't seem to appreciate the dilemma or understand the confusion.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 7 reviewers)

A reviewer said that the participation in workshops with end users, other research institutes, and our Canadian counterparts is commendable. Another said that there was a strong coordination with strong partners, including international partners (Canada). This reviewer wondered if new partners were needed to bring in some fresh ideas, as lack of some partners seems to limit future progress. This was a good effort, according to another reviewer, to establish a collaborative environment with NASA and academia, but the team needs to tie in more with industry and gain from their CFD background and needs to work towards operational effectiveness or the technologies will never get on a truck.

On the other hand, a reviewer could not see how the team planned to do this technology transfer/collaboration. Another reviewer didn't see much interaction with industry, as opposed to research entities. A final reviewer said that it seemed that all the CFD work was done at LLNL with little input from or collaboration with the other labs or industry. The presenter was not aware of the large body of SAE CFD publications and expertise in the automotive industry that would have been very helpful to this project. OEM customers in the industry will always use commercial computer codes. The suppliers provide expert assistance, training, on-going code development, and customer applications. Since DOE and NASA do not provide this service, this reviewer did not expect any customer in the heavy vehicle industry to use these in-house codes for vehicle aerodynamic development. Therefore, trying to validate modeling strategies for in-house DOE/NASA simulation procedures does not support the DOE goals.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 7 reviewers)

A reviewer thought that further use of agencies such as the Sim Center at the University of Tennessee Chattanooga should be beneficial for prediction of potential benefit prior to field testing. Flow conditioning concepts are well worthwhile with high potential payoff, noted another reviewer. Investigation of integrated tractor trailer is dependent on policy issues (will manufacturers be allowed by the FTC to build an integrated vehicle?) not only technical issues. A reviewer noted finally that the companies appear willing to accept the "free help."

On the other hand, the future goals were good, according to a reviewer, especially the industry interaction, but the emphasis on CFD modeling does not seem to be aligned with program goals, especially the stated goal to reduce time to implementation. The error in CFD is on the order of the potential drag improvement of the devices, noted this reviewer. A reviewer said that the limits to improve computational capabilities were not clear. Does future research need more to address physical understanding or computational techniques? A reviewer said that the future research was confusing because it talked about non-CFD areas of investigation: on-road testing, assisting industry, flow conditioning (this reviewer was unsure sure what this is or if it's practical). This reviewer could not determine what or how many codes this CFD project is pursuing and have little confidence it will produce useful information that instills confidence in the community and eliminates any barriers.

Specific Strengths and Weaknesses (Written responses from 7 of 7 reviewers)

- Specific Strengths
  - One of only a few frontiers remaining for improvements in fuel economy of heavy-duty vehicles.

  - Strong science-based approach.
  - The use of versatile CFD tools to evaluate concept potential, such as the blowing idea, is a great use of the technology.
  - Great cooperation among partners.
  - Coordination and information exchange with experimental work is also great.
  - Strong delivery of results.
  - None.
- Specific Weaknesses
  - It is time for additional sanctioned standardized fuel tests for component validation of performance.
  - Needs more new ideas.
  - Computational limitations weren't clear.
  - Goal of designing next-generation tractor-trailer but [researchers] don't have any trailer manufacturers.
  - Perhaps should seek partners outside the truck industry.
  - It was unclear what you were trying to accomplish with this work. Were you presenting a tool or drag reduction devices?
  - How did a 25% drag reduction apply or relate to your work? Difficult to see how things tied together relative to DOE objectives.
  - It eventually competes with full-scale wind tunnel testing. Why CFD? Drag prediction is not the problem—implementation of what is already known is!
  - The CFD challenge appears, to this reviewer, to be so great that attempts to carry out relevant computations is simply instructive by the lack of relevance of his results. Note that he has access to "huge" processing power available to the investigator. Reference a slide discussion of trailer wake details where the simulations minimally capture the pressure distribution details. Note, it was not possible to tell from the Book: was the aft face pressure included?
  - Use of the CFD tool to evaluate drag savings of concepts does not appear to be effective. (i.e. grid resolution issues/errors negate this effectiveness). Focus of CFD needs to be aligned with project goals. Should be used to evaluate concept effectiveness/usefulness and guide experiments, not evaluate/refine modeling strategies.

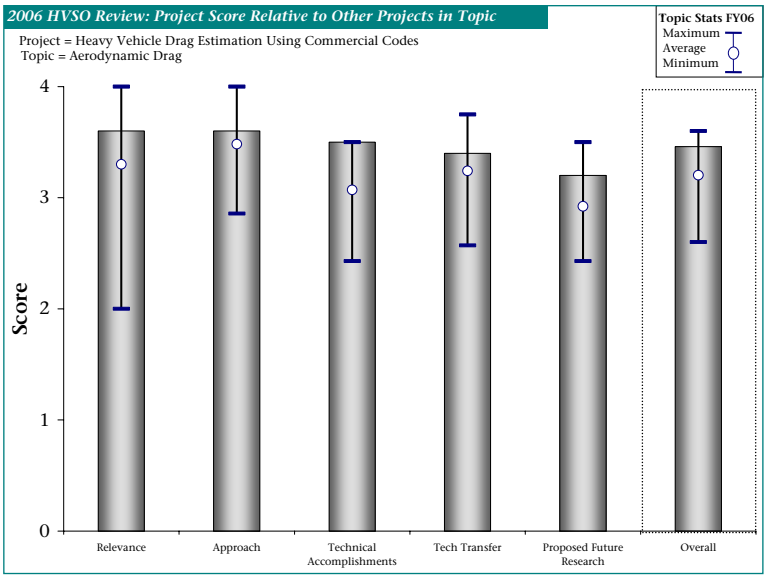
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 7 reviewers)

- Remain cognizant of the daily operational aspects of any device, pertinent to the performance of the driver and the fleet or operator application.
- Clarify whether computation is more limited by physics or math techniques and add specific research program.
- Find a third party that can bridge tractor to trailer integration, such as a large fleet customer.
- Use CFD to determine "increments" in drag coefficient with and without concept for a fixed geometry (no grid resolution issues). Could even expand scope to look at the physics to see why something looks to be effective. Determining whether a concept has "potential" is probably the most effective use of this CFD.
- Rethink this project—it can be a never-ending one, as vehicle geometry changes.
- I recommend this project be cancelled or totally re-directed to support the application of commercial CFD codes for immediate use in vehicle design and development (i.e., STAR-CD, Fluent or PowerFlow for example). These codes have already demonstrated validated, robust modeling strategies for bluff body flow fields and are most likely to be embraced by OEM users. Dr. Pointer's project work on applying STAR-CD to heavy vehicle aerodynamics is an outstanding technical approach and should be replicated in this project.

Aerodynamic Drag

Heavy Vehicle Drag Estimation using Commercial CFD Tools: David Pointer, Argonne National Laboratory

Brief Summary of Project



This project is designed to enable the use of commercial computational fluid dynamics (CFD) software packages to achieve near-term improvements in tractor-semitrailer fuel economy through significant reductions in aerodynamic drag. The researchers are assessing these off-the-shelf codes for their ability to simulate heavy vehicle aerodynamics, and are providing guidance to industrial and laboratory partners on how best to use these codes in aerodynamic simulations.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 5 reviewers)

Favorable comments included that the project meets 21CTP goals and objectives to a high degree. Similarly, it was commented that this was an excellent presentation and a well-organized project with goals and specific deliverables. It will definitely help achieve the DOE goals and objectives. Another comment was that this is a very useful exercise to evaluate what commercial codes can do, their effectiveness, turn around time, and usefulness to industry. Especially notable is the use of codes "as is." The final reviewer said that the project's relevance was good, but seems to be another comparison of CFD versus testing, and not a direct attack on drag.

Question 2: Approach to performing the research and development (Written responses from 4 of 5 reviewers)

Outstanding systematic approach, said a reviewer. Use of codes "as is" is key, according to a reviewer, who also thought the team's focus on turn around time is good coupled with accuracy. The team needs to evaluate effectiveness of more drag reduction concepts as that is the program goal. The team should look at "increments" to eliminate grid resolution issues, according to this reviewer. A reviewer felt there was excellent comparison to experimental data, both drag coefficient and surface pressure distributions. The presenter did understand that percent comparisons alone can be very misleading and avoided using them in his presentation and report. A final reviewer was somewhat surprised by the reference to the differences in model configuration of Peterbilt versus Kenworth, as the Peterbilt Model 387 and Kenworth T2000 are "near twins."

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 5 reviewers)

A reviewer noted that the accomplishments cite the beneficial application of CFD tools for drag reduction prediction. Second, the authors have good insight to OEM user needs; they are looking at the accuracy of quick-turn-around modeling processes. It appears overnight solutions will be very good, in this second reviewer's opinion. The third reviewer said the team demonstrated a good turn around time, and good interaction with industry. Accuracy of results requires high grid resolution (no surprise) and thus the use of CFD "increments" should be used. Overall, not too many results on the effectiveness of drag reduction devices. (Not too many actual "results").

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 5 reviewers)

Good interaction with major OEM (two trucks), one engine provider, and one device supplier, noted the first reviewer. Second, the CRADAs with industry are well crafted and organized. They will produce some good results, in this reviewer's opinion. Finally, a reviewer thought that there was a good tie-in with industry and manufacturers, but the project could use more tie-in with other concept generators (i.e. universities, small business) but others are doing this. This reviewer noted the project is driving hardware development (i.e. frontal area study

with Caterpillar).

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 5 reviewers)

Future focus statement demonstrates relevant continued research, according to a reviewer. Future plans are focused on delivering timely results, noted another. Finally, a commenter noted the project's good focus, but that the team should identify other concept manufacturers and should use wind averaged drag concept (or evaluate effectiveness of doing this).

Specific Strengths and Weaknesses (Written responses from 5 of 5 reviewers)

- Specific Strengths
  - Good collaborative effort.
  - Outstanding work and presentation. Can't say more. It demonstrates what I would expect from this DOE effort.
  - Working with PACCAR and Caterpillar, et. al.
  - Outstanding work—well planned and executed. I completely agree with the STAR-CD modeling approach.
  - Use of commerical "as is" codes. Good integration with manufacturers. Evaluation of concepts at the level that OEMs can accomplish.
- Specific Weaknesses
  - None.
  - Needs end-user input (if applicable).
  - Grid resolution issues compromise effectiveness of tool as a quick turn around evaluation. Need to look at a variety of devices.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 5 reviewers)

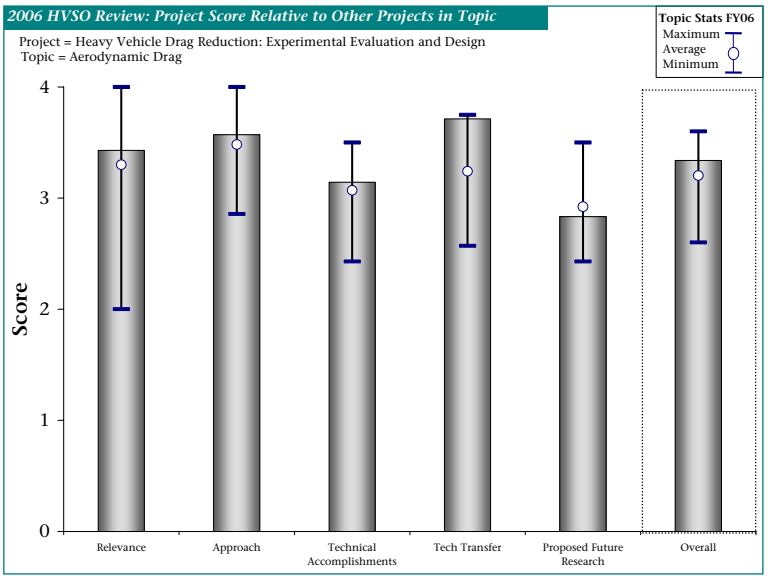
- For radiators look at placement—sides, rear of tractor—incorporated in structure as in World War II aircraft.
- Contact Aerovolution and include some modeling to define improvements to this inflatable boattail. It has more potential.
- Suggest the use of "increments" on a fixed grid resolution of evaluate device effectiveness and make recommendations on device effectiveness. Perhaps look at wind averaged behavior.

Aerodynamic Drag

Heavy Vehicle Drag Reduction: Experimental Evaluation & Design: James Ross, National Aeronautics & Space Administration

Brief Summary of Project

The objective of this project is to provide high-quality aerodynamics and flow field data for CFD validation and improved physical insight into truck aerodynamics. In this project, researchers are also evaluating aerodynamic drag reduction concepts and providing guidance to industry on aerodynamic testing issues, particularly Reynolds number effects.



Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 7 reviewers)

Like previous presentations in this review, this project seems to conform to 21CTP requirements, according to the first reviewer. A second reviewer thought testing for aerodynamics is directly connected to goals. Third, a reviewer said that the project objectives are well-defined and do support the DOE program. The experiments have been well selected, said another. The results give insight into the flow features that can be related to practical configurations even though the model geometries are simplified. Connections to industry are quite appropriate. In another's view, the experimental evaluation/validation is key for screening concepts and establishing benchmarks. This project offered good generation of data for CFD validation. A final reviewer said that the work seems to be focused on everything but "REDUCING DRAG"—a direct approach. The project is another one analyzing the phenomena "to death," while known devices/techniques languish.

Question 2: Approach to performing the research and development (Written responses from 4 of 7 reviewers)

First, the approach offered good validation of computation: this reviewer wondered if experimental techniques would be able to analyze complex structures (like truck underbody). A second reviewer said the approach was good within the narrow focus of this work. Lastly, a reviewer offered that there was a systematic approach to evaluation. Many concepts were examined but this reviewer did not see any summary of results on presented concepts.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 7 reviewers)

A reviewer noted the use of wind tunnel and road tests, both of which are absolutely necessary. Another said that the new/improved experimental techniques are an excellent investment for this and future efforts: low-speed pressure sensitive paint and wall shear stress are clearly useful. The developed Reynolds criteria are clearly valuable as required conditions. A reviewer said that good advances in experimental techniques need to match models. Further, a reviewer noted the good results for understanding physics, and the good spin-off of technologies from program (i.e. large scale PIV development). However, there was a lack of results presented in this commenter's viewpoint. What works? What doesn't? Is the data available for use? Finally, a reviewer said that the presentations and supporting material were not well organized, wandered a little and were very different from the handouts given to the reviewers. Therefore, it is hard (in this reviewer's view) to assess accomplishments and progress.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 7 reviewers)

Excellent interaction with some of the most prominent entities, said the first reviewer. Second, a reviewer said there was good coordination with national labs and academia. The team could integrate more with industry (there is some) but may be adequate for now. Finally, the presentation states, but did not elaborate on, industry

cooperation/involvement, in this reviewer's opinion.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 7 reviewers)

All items listed in the future work slide are most relevant, noted the first reviewer. The second reviewer thought there was a rational path forward. Alternatively, a reviewer said that the future work wasn't clear, and it appears that the researchers are waiting for customers/collaborators. Finally, the future work was not really defined too well with respect to program goals, in a reviewer's viewpoint. There seems to be more complimentary data than rather than data focused on drag reduction device evaluation.

Specific Strengths and Weaknesses (Written responses from 6 of 7 reviewers)

- Specific Strengths
  - Excellent collaborative efforts.
  - Advances in techniques.
  - Reliability of the data/cross checking of techniques.
  - Wide range of tests conducted.
  - Great expression of new ideas.
  - Especially impressed with and satisfied with the Reynolds number work. It clearly demonstrates that Reynolds number work and decisions for operating conditions were right relative to previous work done at International.
  - One strength is the guidance on minimum Reynolds number for testing and the insight into important time-averaged flow field characteristics.
  - Great database for CFD. Helps to understand physics. Capability to quantify results at full scale.
- Specific Weaknesses
  - None noted.
  - Could use end-user input (if applicable).
  - Future directions aren't clear.
  - Future programs: would like more definition on proposed directions.
  - Need more techniques for small details and real-time measures.
  - CFD validations: have heard three now. Isn't there a lot of duplication of effort?
  - Not very much data reported on the effectiveness or even relative effectiveness of drag reduction devices: drag coefficient comparison.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 7 reviewers)

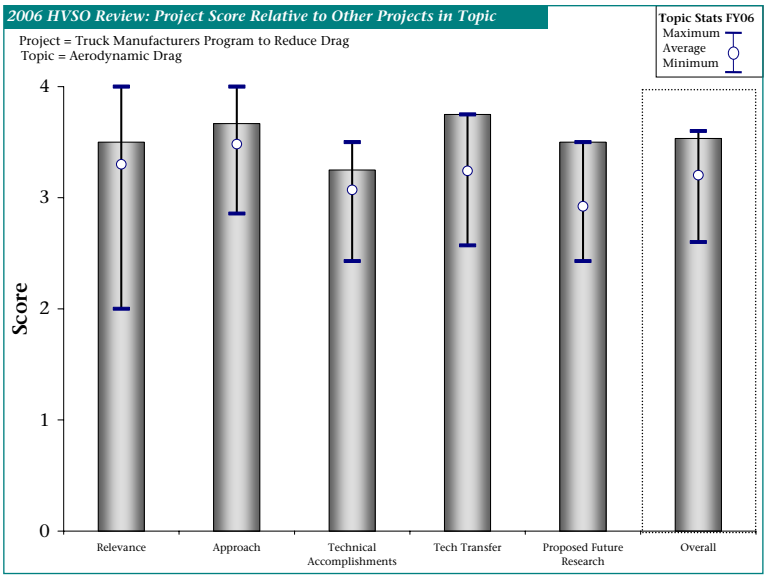
- Include end users in future work.
- Continue to stay close to industry.
- Clarify future direction.
- Collapse all the CFD validations into one project.
- Define role and goal in support of program goals in a better way. Quantify results of various devices (drag coefficient and fuel efficiency).

Aerodynamic Drag

Truck Manufacturers Program to Reduce Aerodynamic Drag: Robert Clarke, Truck Manufacturers Association

Brief Summary of Project

In this project, a consortium of four major heavy truck manufacturers are determining aerodynamic drag/fuel economy effects of additions or changes to Class 8 tractor-semitrailer configurations through a combination of analysis, wind tunnel testing, and on-road vehicle testing. Partners include Freightliner, International, Mack, and Volvo.



Question 1: Relevance to overall DOE Objectives (Written responses from 2 of 4 reviewers)

The first reviewer felt the project meets 21st Century Truck Partnership objectives. The second noted that this project is very well-aligned with the goals of the 21CTP program to improve fuel economy on the road, and felt that this was an excellent presentation.

Question 2: Approach to performing the research and development (Written responses from 2 of 4 reviewers)

The first reviewer stated that since TMA in this instance is in mostly a consulting role, it is difficult to improve on. The second reviewer noted duplication of efforts.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 4 reviewers)

All collaborator accomplishments are very significant, said the first reviewer. The second commenter liked the project structure and accomplishments.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 4 reviewers)

The review panel noted that industrial partners are full participants, but felt that contact with other research institutes, other than OEMs and Tier 1 providers, would be beneficial.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 4 reviewers)

In the role of consulting, TMA seems to be on track with industry needs, noted the first reviewer. Another reviewer suggested that the project team simply execute the future research plan. The third reviewer said that the project should not be allowed to end at completion of Phase II.

Specific Strengths and Weaknesses (Written responses from 4 of 4 reviewers)

- Specific Strengths
  - TMA is an entity already heavily involved and knowledgeable on most issues facing the end user.
  - Industrial partnership.
  - Going the right direction.
  - Test and on-road verification of results. Conceived and implemented by those who will have to build and implement these improvements and prime the marketplace for them.
- Specific Weaknesses
  - None.
  - TMA needs interaction with research institutes, as far as presenting end user concerns.

– Appears to have excess duplication of efforts. Needs active and apparent collaboration of trailer OEM and possibly the same relative to the end customer.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 4 reviewers)

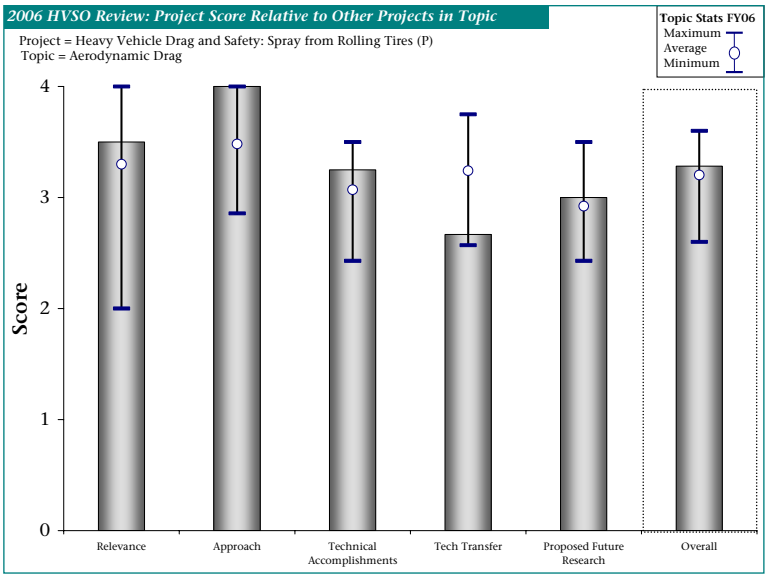
- None.
- New ideas on possible advanced shapes rather than fixes to existing shapes. May be very difficult because of end use but the same problem existed when designing aero tractors.
- Address a totally integrated tractor/trailer system.
- Enhance this project to maximum extent possible. Do not let it end at the end of Phase II.

Aerodynamic Drag

Heavy Vehicle Drag and Safety: Spray from Rolling Tires (Poster): Fred Browand, University of Southern California

Brief Summary of Project

Researchers in this project have developed a novel technique for studying the spray characteristics of rolling tires from a fluid dynamics perspective in order to ensure the safety of drag reducing devices in the presence of sprays from these tires. The team plans to use the physical understanding gained from these experiments as a means to mitigate spray from heavy trucks.



Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 4 reviewers)

Reviewers generally agreed that the project has some relevance to DOE objectives, at least peripherally. The first reviewer said that the project addresses the safety part of mission statement (helps ensure that aerodynamic solutions won't hurt safety): the project doesn't directly address reduced energy usage. Another said that it was a good idea to see the effect of devices on spray from vehicles. The third said that splash and spray is officially a nuisance, not a safety problem (according to NHTSA who couldn't make a case for it as a safety problem). However, there is a definite aero (e.g. trailer side skirts) safety connection and reducing splash and spray will improve truck driver vision via the mirrors. The final reviewer noted that the relevance is dramatically shown when one drives in heavy truck traffic in a heavy rain. (Good topic selection!)

Question 2: Approach to performing the research and development (Written responses from 3 of 4 reviewers)

Comments on the approach were generally favorable as well. One comment was that the team had a unique approach to attack the spray question. This is the only study that this reviewer is aware of that seeks to understand the basic physics. The second reviewer said that their approach is innovative and rational. Finally, a comment was offered that this was a great technique to study in the lab, but it needs to be correlated to observations from the road (effect of vehicle).

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 4 reviewers)

The first reviewer asked about how much of a goal safety is for DOE, as it is not their responsibility. Similarly, a reviewer said that by 2003 DOT and NHTSA had abandoned research on spray reduction because progress had stopped and there were no new ideas. This new approach with its demonstrated technical capabilities has the promise of making breakthroughs in technical understanding which may enable creation of new solutions which can be applied. Finally, a reviewer offered that the team's efforts are roughly halfway through. The experimental techniques are clearly valuable. They will have to accelerate to meet the promise of this effort.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 4 reviewers)

The first reviewer said that technology transfer was hard to judge. A second reviewer asked if the team communicates and coordinates with the DOT (NHTSA, FMCSA). Thirdly, a reviewer commented that the project brings together the unique talents of DOE aerodynamics modeling, USC measurement and modeling capabilities, and Michelin tire expertise. None of the partners could do this alone. This unique collaboration has led Michelin to contribute an additional $92k to the project this year plus giving additional test tires and engineering hours. Lastly, a commenter noted that the close ties with Michelin are a positive aspect of the work; hopefully this will be realized. Having Michelin staff participate would be even better.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 4 reviewers)

One reviewer felt the future research embodied solid deep science and physical understanding approach coupled with modeling and testing of physical solutions that could be commercialized. The other commenter said that the future plans were not detailed on the poster very well.

Specific Strengths and Weaknesses (Written responses from 2 of 4 reviewers)

- Specific Strengths
  - Deep science, basic physics are being used to bring new understanding. Strong industry, university, and DOE laboratory collaborations.
  - The impact of any geometrical changes to the vehicle could have an effect on spray patterns. Any worsening (or improvement) to this needs to be determined.
- Specific Weaknesses
  - Need to better lay out and closer couple aerodynamics and physical phenomena modeling of LLNL to current USC study.
  - Evaluation of in-situ effects not well presented.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 4 reviewers)

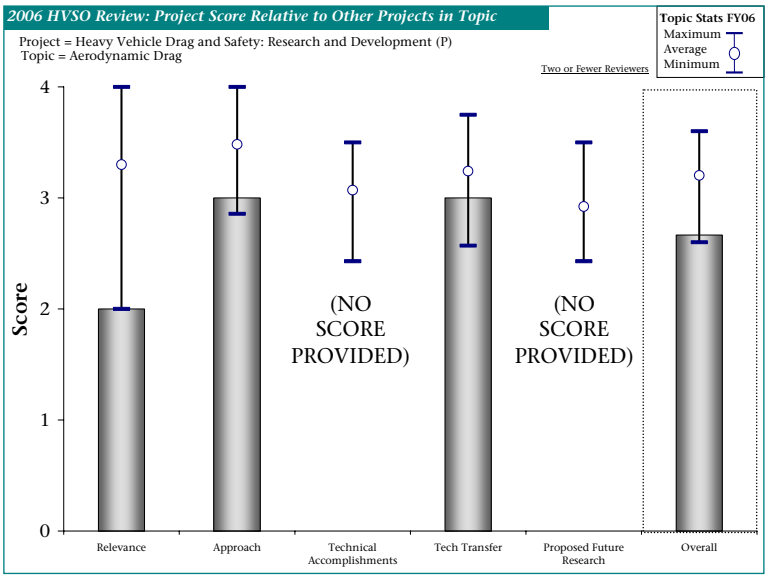
- Enlarge scope to closer couple with DOE Aero Consortium modeling and aero testing. Open up potential for a full vehicle systems solution (tire and vehicle design).
- Include effect of spray in the wake in addition to passing or incoming.

Aerodynamic Drag

Heavy Vehicle Drag and Safety: Research and Development (Poster): John Paschkewitz, Lawrence Livermore National Laboratory

Brief Summary of Project

In this project, the research team is investigating the effects of drag reduction devices on trailer brake light visibility reduction due to splash, motorist passing visibility, and vehicle stopping distance.



Question 1: Relevance to overall DOE Objectives (Written responses from 1 of 1 reviewers)

Only one reviewer commented on this project, noting that this project seems duplicative or competitive with the Browand, et.al. project. This reviewer asked if these could be combined to save on resources.

Question 2: Approach to performing the research and development (Written responses from 0 of 1 reviewers)

The only reviewer of this project did not offer any written comments on this aspect of the research.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 0 of 1 reviewers)

The reviewer did not provide written comments on this project aspect.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 1 of 1 reviewers)

The reviewer said that the team at least mentioned Michelin and DOT. This reviewer wondered if the researchers were aware of the TTI work done years ago, as it looks like they are repeating some of what was done back then.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 0 of 1 reviewers)

No written comments were provided on this research aspect.

Specific Strengths and Weaknesses (Written responses from 0 of 1 reviewers)

- Specific Strengths
  - None provided.
- Specific Weaknesses
  - None provided.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 1 reviewers)

- Combine with Browand's effort.

Projects in this category are examining ways to reduce friction and wear in drivetrain components, through employment of advanced coatings and other methods. The goal of this category is to reduce friction and wear and enable a 3-4% increase in fuel economy. This category also contributes to the overall heavy vehicle systems optimization goal of increasing fuel efficiency by 25% by reduction in parasitic losses.

Below is a summary of average scores for 2006 for the four projects in this category, along with the average, minimum, and maximum score for all projects in this report. The highest score in this category for each question is highlighted.

Summary of Scores for Projects in this Section

Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomp-lishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
20	*Boundary Lubrication Mechanisms: A Systems Approach:* Oyelayo Ajayi, Argonne National Laboratory	**4.00**	**4.00**	**4.00**	3.33	3.75	**3.82**
22	*Efficiency Improvement through Reduction of Friction & Wear in Powertrain Systems:* Bohdan Lisowsky, Eaton Corporation	3.80	3.80	3.60	**3.80**	3.60	3.72
24	*Parasitic Energy Loss Mechanisms: Impact on Vehicle System Efficiency:* George Fenske, Argonne National Laboratory	3.60	3.60	3.40	3.20	3.60	3.48
26	*Superhard Coatings for Advanced Vehicle Systems Applications:* Ali Erdemir, Argonne National Laboratory	**4.00**	3.50	3.60	**3.80**	**4.00**	3.78
	Average Score for This Category	**3.84**	**3.72**	**3.63**	**3.56**	**3.74**	**3.70**

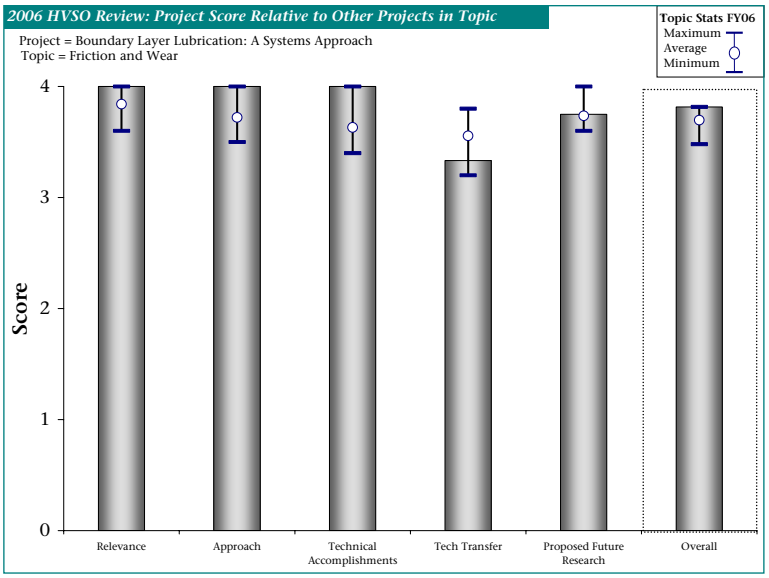
Overall Program Scores

	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
Overall Program Average	3.52	3.51	3.25	3.27	3.24	3.36
Overall Program Maximum	4.00	4.00	4.00	4.00	4.00	4.00
Overall Program Minimum	2.00	2.67	2.33	2.00	2.43	2.60

Boundary Lubrication Mechanisms: A Systems Approach: Oyelayo Ajayi, Argonne National Laboratory

Brief Summary of Project

The goal of this project is to develop a better understanding of boundary lubrication mechanisms and the failures of those mechanisms, using a systems engineering approach. This project contributes to DOE goals of reducing parasitic energy losses and improving vehicle efficiency.



Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 4 reviewers)

The first reviewer strongly believed that this project addresses a key goal of the DOE program and, moreover believed that this aspect is highly likely to lead to significant benefits for industrial partners and accumulation of energy and cost savings to the USA. A second reviewer offered that a detailed study of boundary lubrication is very timely: much of the heavy vehicle machinery operates in that range and it is becoming possible to study the film in detail at the necessary nanoscale. A third reviewer said that these authors show the important role of the metal (iron + steel) in failure resistance of lubricated systems. The composition of the sliding bodies is usually neglected in tribological analysis. Finally, this project area is very nicely focused on some of the key issues that need to be resolved in advancing the capability to predict the behavior of materials under conditions where catastrophic failure can occur during sliding contact with or without lubrication, according to the final reviewer.

Question 2: Approach to performing the research and development (Written responses from 4 of 4 reviewers)

Comments on the approach were quite detailed. The focus on fundamentals of boundary-layer lubrication is highly important. All too often, researchers rush toward finding a solution to a complex problem, only to learn later that its fundamentals were not studied sufficiently well to allow us to solve the problem. Examination of scuffing is highly important and the investigators are fortunate to have good access to Argonne's APS. It is the single most powerful tool in the USA for study of surface phenomena. This reviewer expects great things from the pending in situ experiments on the APS. A second reviewer felt that the development of instrumentation for in-situ or near in-situ observation of boundary layer film formation is a very exciting approach. In the end, however, it will be necessary to also address how the film forms by tribochemistry and how it wears. Another reviewer noted that these authors are using new methods and instruments to look into the very dynamic contact region, approaching real time. Finally, a reviewer said that the approach to this project appears to be very well thought out and addresses the most significant technical barriers involving boundary lubrication.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 4 reviewers)

Building the new facility on APS is a highly important and unique accomplishment, said the first reviewer. Its usefulness going forward should be outstanding. The new insight into scuffing and the model developed to describe it constitute significant advances. This reviewer is very much a believer in experimental verification of any model and the experimental work to date has been quite impressive. A second reviewer stated that the project is fairly new, and that progress seems to be fine. There still is a long way to go before a full understanding of film formation and destruction has been obtained, if ever. The third reviewer simply said that these authors are making very real progress. The last reviewer offered that development of a tribo-tester that is capable of allowing surface films to be analyzed in-situ is an outstanding achievement.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 4 reviewers)

Review comments were mixed for technology transfer aspects of this research. This project is decidedly more fundamental than many in the 21CTP program, in one reviewer's opinion. Thus the interactions with industry have not produced direct funding. The focus of the program is, however, on industrially relevant work, and this reviewer expects increasing industrial buy-in over time. Another noted that the usage of some of this capability by Caterpillar is significant, and thought it would be good to see it being transferred more broadly in other areas of industry. A reviewer felt that it was unclear if any technology transfer is ongoing. Finally, a reviewer said that the Argonne technology is not readily transportable because of the uniqueness of the instruments. However, ANL encourages investigators to come and use ANL instruments, and there are several post-Ph.D. students working on the project.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 4 reviewers)

The first reviewer noted that the design and component development efforts appear to be appropriately targeted and the proposed experiments on APS have been selected well to achieve maximum benefit. This reviewer would prefer to see additional materials characterization efforts and more post-mortem studies. A second reviewer offered that the plan seems well laid out, and that an important first step is the development of the new instrumentation. Third, a reviewer said that this group is well prepared to make very important progress in the future. Finally, a reviewer felt it would be significant to extend the applicability of the scuffing prediction capability to other materials such as ceramics and thin coatings on useful substrates.

Specific Strengths and Weaknesses (Written responses from 4 of 4 reviewers)

- Specific Strengths
  - This group uses the most advanced technology available anywhere.
  - Strengths include targeted use of APS, excellent balance between modeling and experiment, good approach to study of an important, but highly complex problem.
  - Development of advanced techniques for analyzing boundary layer film in-situ.
  - Development of more detailed expressions for scuffing susceptibility.
  - The development of a model that addresses scuffing phenomena is a very important and laudable achievement. The extent to which a resource such as the APS can be applied is unique and could enhance the knowledge base of boundary lubrication many times.
- Specific Weaknesses
  - Weaknesses include lack of industrial support and somewhat limited data acquired to date. This project must (1) make quick use of its new facilities and (2) produce and analyze new sets of data.
  - Perhaps ultimate goal of "full understanding" is a bit unrealistic. Since we mostly want to get away from ZDDP, we don't really need to know all about it, just enough to emulate it.
  - Inadequate funds.
  - More collaboration with other areas of industry and academia is needed.

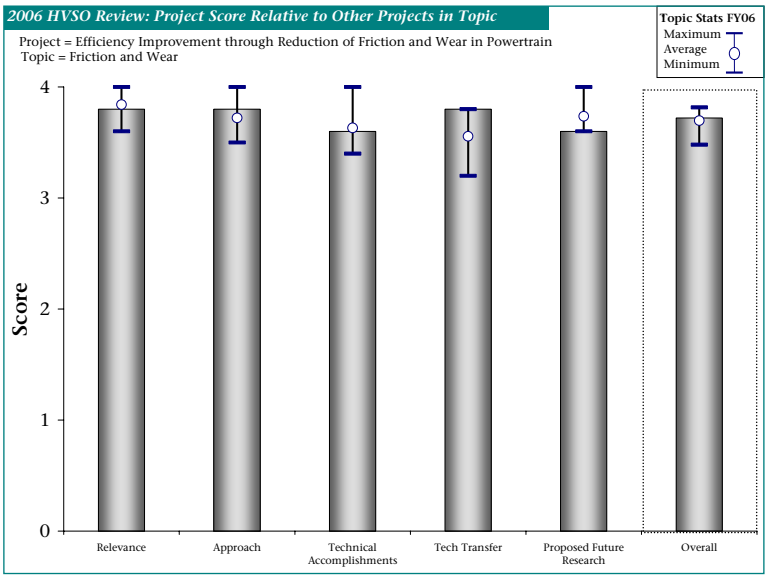
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 4 reviewers)

- None.
- Keep going.
- I would like to see a microstructural study of the scuffing to supplement the more general bulk results.
- The scope as outlined for future work is good. More extensive collaboration is needed to really make an impact.

Friction and Wear

Efficiency Improvement through Reduction of Friction & Wear in Powertrain Systems: Bohdan Lisowsky, Eaton Corporation

Brief Summary of Project



In this project, Eaton is conducting research and development to reduce friction and parasitic energy losses in truck transmissions and axles. In addition, they will be creating an integrated component design and analysis procedure to minimize friction and oil churning losses without compromise in performance and durability.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 5 reviewers)

Review comments were generally positive about this project's relevance. First, a reviewer said that driveline efficiency needs attention. This project is more interesting to the military because of heavy payloads and slow speeds which reduce attention on aerodynamic drag and focus attention on mechanical and electrical efficiencies. The project efficiency improvements are comparatively large. A second reviewer noticed that this presentation was the only one to elicit not one single question. The goals of the program were clear and commendable, the results to date outstanding, and the plans compelling, so there was no need to ask a question. A third reviewer said that the project was well focused on providing necessary models for boundary lubricated situations, especially including surface roughness and texture. This group is doing much work in the right direction, said another reviewer. Finally, this effort is addressing the needs to optimize systems in its combination of modeling and testing to improve the application of appropriate lubricants, surface textures and materials to achieve better component performance in gears and bearings.

Question 2: Approach to performing the research and development (Written responses from 5 of 5 reviewers)

Approach comments are quite positive as well. The first reviewer characterized the approach as fundamental and analytical, but practical. Another noted that the thirteen sets of studies constitute a comprehensive approach to this difficult challenge. This project has an excellent balance of modeling and experiment, supported by outstanding insight into key problems to be addressed. Good team, commented another, who singled out the well-distributed efforts on this research. The work is broad-ranging, said another reviewer. Finally, the combining of efforts at the national lab with those at industrial participants and academia makes for a good overall approach that is achieving excellent results. The main technical barriers have been identified and addressed appropriately.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 5 reviewers)

Reviewers had a high opinion of the technical accomplishments as well. A reviewer thought that the team had made significant findings and presentation in technical literature. Another noted the excellent agreement between experiment and model, and felt it was a fine study of effects of surface condition. A third reviewer said the work seems to be coming along very well. Finally, a reviewer said that excellent progress has been demonstrated towards the goals of the research.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 5 reviewers)

The first reviewer said that this project is another very good example of how collaborations between government, industry, and academia can produce excellent results. Four collaborators are listed, said another. The partners appear to be closely coordinating, noted another. A reviewer highlighted the good team that represents various players. A reviewer noted that execution of the program under Eaton (as opposed to the other partners) provides

the best likelihood of commercial application. Further, Eaton is holding up its end of the support and has clearly identified this work as important to its future business.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 5 reviewers)

Reviewers had a high opinion of the future research. A reviewer said that the efforts are clearly focused on attaining commercial application. Another noted the great collaborations and the clear path toward commercialization. A reviewer suggested that additional emphasis on addressing durability would be good, as it was only mentioned in passing in the report. Further use and integration of modeling capability in the area of boundary lubrication is very much needed, offered the final reviewer.

Specific Strengths and Weaknesses (Written responses from 5 of 5 reviewers)

- Specific Strengths
  - Fundamental, analytical, but practical.
  - Strong corporate support, excellent insight into challenges and how to overcome them, talented team.
  - This is a good teaming effort.
  - Very relevant, well distributed tasks.
  - They focus their work on models and verify models via bench testing.
- Specific Weaknesses
  - None.
  - None noted.
  - Weaknesses are hard to find.
  - Forward planning could be expanded.
  - They would benefit from a more fundamental approach, including a focus on the nature of boundary films.

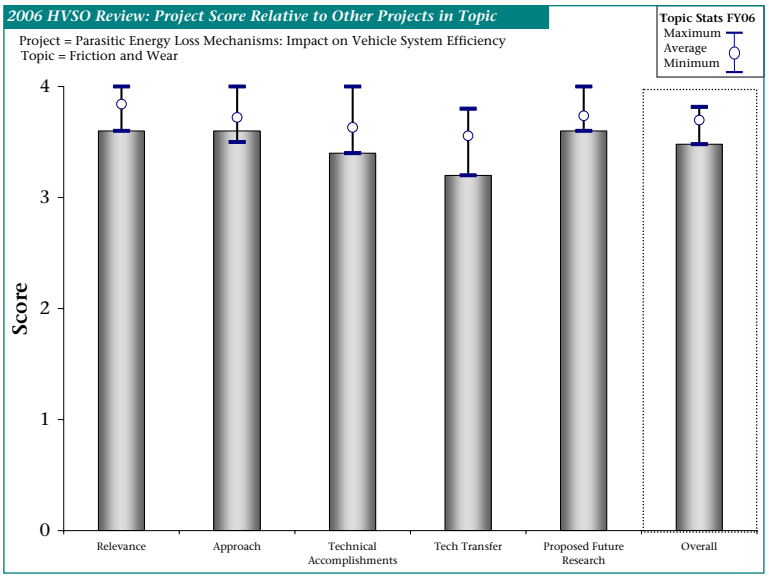
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 5 reviewers)

- No obvious changes or additions would be recommended.
- This effort offers significant military benefit because it will be implemented at a low enough hardware level that it should go unnoticed and thus can't be rejected as "new." The contribution to fuel economy will be a significant increment.
- In an ideal world, I would prefer to see more emphasis on durability testing. Validation of commercial utility requires it.
- They would benefit from a more fundamental approach, including a focus on the nature of boundary films.

Friction and Wear

Parasitic Energy Loss Mechanisms: Impact on Vehicle System Efficiency: George Fenske, Argonne National Laboratory

Brief Summary of Project



This project has several overall objectives: increase fuel efficiency through engine friction reduction; develop mechanistic models of parasitic engine losses and integrate these with vehicle system analysis codes; validate these models and codes with experiments; and identify/assess advanced tribological concepts to reduce engine friction.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 5 reviewers)

Several reviewers noted that the project was relevant, one noting that it meets 21CTP objectives, and another saying that the work in this area is very focused on one of the key technological areas requiring improvement in the 21st Century Truck Partnership. A third reviewer commented that this was a useful and necessary modeling effort to identify areas where tribology/surface engineering efforts can have the greatest effect. A final reviewer offered extensive comment on the work's relevance: the focus of the project is timely and its relevance to DOE's stated objectives is excellent. It is clear that for large trucks the biggest potential fuel savings will come from reduction in drag. To this reviewer, however, this program fills an important niche and offers a unique opportunity to obtain near-term and longer-term substantive gains in fuel efficiency and economic position. Aero drag reductions rely to a large extent on trailer manufacturers, who are collectively far from progressive and are generally bereft of surplus cash. The fuel reduction efforts in this program rely, in contrast, on tractor and engine manufacturers, who collectively are progressive and "comparatively rich." This reviewer felt that they are far more likely to invest in new technologies that offer advantages. Taking this argument further, US manufacturers that adopt new fuel-efficient approaches will be likely to increase exports. In most of the rest of the world, trucks drive slower and for shorter distances than in the USA. Thus, the technologies under investigation here are the ones most likely to be adopted in foreign countries. This reviewer believed that efforts on friction reduction will lead to significant energy savings and improvements in balance of payments.

Question 2: Approach to performing the research and development (Written responses from 4 of 5 reviewers)

The first reviewer thought the methods citing for measuring friction and resistance are very innovative: this may be one of the last remaining venues for improving fuel efficiency at the engine level. Another felt that this project is well organized and utilizes the strengths of the lab to a great extent. A third reviewer said that the results of this effort should provide at least part of the justification for other work. A final reviewer thought there was a solid balance between modeling and experimentation, and a good focus on promising candidates. In this reviewer's opinion, though, the characterization efforts on the superhard coatings have been insufficient and the focus on surface texturing cannot be justified going forward.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 5 reviewers)

A reviewer thought there was extensive information that fleets and engine manufacturers alike should find valuable. Another felt that the accomplishments to date have been impressive, especially the facilities upgrades. The program seems to be well-positioned for the next stage of work. A third reviewer said that good progress has been demonstrated in carrying through on the overall program plan and scope in this area. The final reviewer said that the project does not seem to have run into any major barriers on its own: it is a fairly straightforward modeling effort with some validation. It is addressing one of the DOE program problem areas, which possibly could be called a "technical barrier."

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 5 reviewers)

First, a reviewer said that the team has had good interactions with an engine provider, Tier 1 drivetrain providers, academia, and engineering lab. Another felt that there appears to be a good level of effort to integrate work at the lab with industry and universities. The teaming of Eaton and Caterpillar with Northwestern University is a good example of how such collaborations can offer synergies that make progress possible in very difficult areas of technological advancement. A reviewer said that there were reasonably strong collaborations in this project, but quite clearly significantly increased cost-matching from industry is required. One presumes that such support will emerge over the next year. If it does not, the rating would obviously drop significantly for this reviewer. A final reviewer said that it was not exactly clear how much tech transfer has been done: Ricardo is doing modeling, University of Michigan will be doing engine testing, so collaboration is good (perhaps too much work farmed out?)

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 5 reviewers)

An initial review comment was that the future research seems well laid out. Another said that the future activities presented appear to mesh well with past accomplishments and needs for further advancements. A third reviewer noted that further information on this subject of parasitic losses will be evident with inclusion of additional parasitic consumers, i.e. compressors and present cooling fan configurations. The final reviewer commented that the project team has good plans overall, but based on the presentation, supporting documentation, and goals of 21CTP program, it seems to be necessary to move more rapidly toward commercialization. Focusing on strengths, such as coatings, and eliminating efforts such as surface texturing should allow the work to progress more rapidly.

Specific Strengths and Weaknesses (Written responses from 5 of 5 reviewers)

- Specific Strengths
  - The people working on the project are doing well.
  - One of the last areas for improvement at the engine level.
  - Identifies critical areas for future efforts, focused on tribological opportunities.
  - Strengths include strong collaborations among a talented team with good complementary expertise, excellent equipment, and significant advances in production of promising coatings.
  - A good team of people have been working on this project. The technical requirements are difficult, but good progress has been made to show how improvements in friction might be achieved and the extent to which advancements in this area can be expected to help achieve the overall mission of improved fuel economy in heavy vehicles. Many of the same improvements can be implemented in other fields as well.
- Specific Weaknesses
  - Needs end user input (if applicable) and focus on products already required for five to ten years ahead.
  - The talk was shorted so that perhaps I did not hear enough, but based on what was presented the surface texturing work is a comparative weakness.
  - Not clear how reliably the single cylinder data can be obtained and related to modeling results: presumably to come.
  - There are too few working on the problem to really understand all of the issues. One major issue is devising more realistic bench tests and connecting the bench test results to the practical range of engine operation.
  - Probably a difficult area for this work is the participation of oil industry representatives who have something to gain and a lot to contribute to the improved understanding of frictional behavior as it relates to lubricants and additive systems. Much of their efforts are quite proprietary, but cooperation in this regard would benefit the total effort significantly.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 5 reviewers)

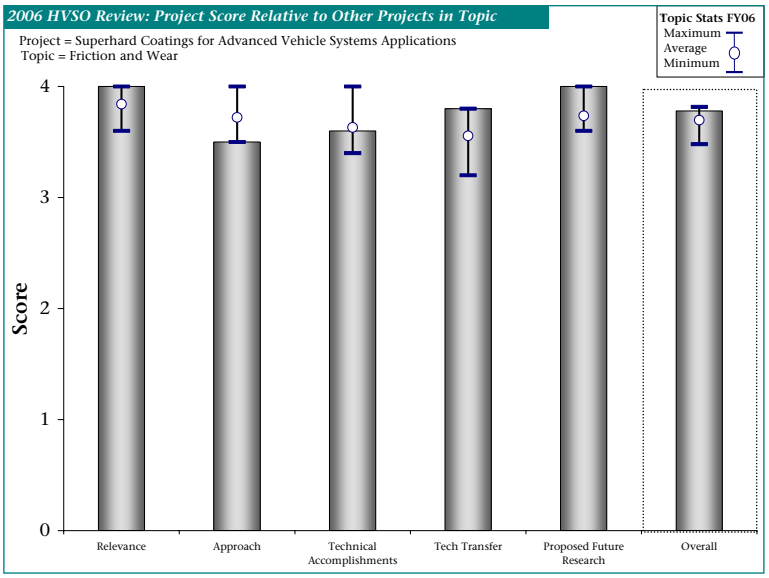
- None.
- Perhaps fleets and operators could be included in real-world oil sampling.
- Characterization work should be increased; surface texturing deleted perhaps.
- There should be much more knowledge of basic boundary lubrication/additive chemistry.
- The current scope is good, but more could be done with the addition of some oil/additive industry participation.

Friction and Wear

Superhard Coatings for Advanced Vehicle Systems Applications: Ali Erdemir, Argonne National Laboratory

Brief Summary of Project

In this project, ANL will be designing, developing, and optimizing superhard and low-friction coatings to increase durability and reduce parasitic energy losses in engines. Residual stresses in these coatings will be measured as a function of thickness, and these will be related to processing, properties, and adhesion. The potential for large-scale production of such coatings will be demonstrated, and implementation of the technology into engine systems will be performed.



Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 5 reviewers)

This project very appropriately supports DOE's mission in identifying materials that promise to foster friction reduction capability while greatly enhancing wear life and functionality in critical tribological systems, based on the first reviewer's opinion. A second comment was that hard coatings are likely to strongly influence component durability. The third reviewer offered extensive comments, beginning with the statement that the relevance to DOE's stated objectives is excellent. This program offers a unique opportunity to obtain substantive gains in fuel efficiency and economic position. The reduction efforts in this program rely on adoption by tractor and engine manufacturers, who collectively are progressive and comparatively rich. They are likely to invest in new technologies that offer advantages. Taking this argument further, US manufacturers that adopt new fuel-efficient approaches will be likely to increase exports. In most of the rest of the world, trucks drive slower and for shorter distances than in the USA. Thus, the technologies under investigation here are the ones most likely to be adopted in foreign countries. The final reviewer felt that this is a very relevant project, although almost everything has to be accepted on faith: no details, sometimes coating seems to have nanograins, sometimes columnar grains, and very few property data are given.

Question 2: Approach to performing the research and development (Written responses from 4 of 5 reviewers)

The appropriate technical barriers are being addressed for development and implementation of high tech coatings with superior performance characteristics, according to the first reviewer. Second, a reviewer felt that these authors use the best of tools and do it well. A reviewer felt that the approach may well be excellent, but details provided are vague (perhaps justifiably so, but perhaps it could have been indicated). The aspects of running in a related tribochemistry should be explored. The final reviewer said that based on the presentation, significantly more effort should be expended on characterization of the superhard coatings. Without better understanding of exactly what they are, it will prove to be difficult or impossible to manufacture them reliably or to optimize their properties. For example, based on the limited data presented in this and related talks, it seems that surface roughness is a critical parameter in determining friction coefficient, but Dr. Erdemir did not report any such values for his coatings.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 5 reviewers)

Outstanding coatings have been produced on both test substrates and real components, in one reviewer's opinion, and this reviewer also felt that superior properties have been reported. A second reviewer noted that Erdimir has developed many new coatings so far. Third, the ability to measure residual strains in thin coatings is an achievement that promises to significantly enhance future developments in the coatings field. Finally, a reviewer said that the project has made good progress, but it seems to be progressing very slowly (ANL has talked about these coatings for years.) The separate internal stress determination technique seems to be a nice addition.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 5 reviewers)

An initial review comment was that this is a great group of collaborators that represent all parts of the system (engine, transmission, coating manufacturers). A second review comment was that the technology transfer seems to be well underway but not discussed in much detail. Another noted that many manufacturers have bought license to use ANL coatings. Similarly, a reviewer pointed out that a very high level of industrial interest has been demonstrated in the number of industrial companies that have expressed an interest to transfer this technology and put it into practice. A final reviewer said that the researchers mentioned the existence of significant industrial interest and that agreements can be negotiated. Given the comparatively basic nature of this work, the proposed timescale for bringing industry into the project appears to be appropriate. If, however, no industrial buy-in occurs over the next year, then the goals and approaches of this project would require re-examination, this reviewer felt.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 5 reviewers)

A reviewer said that the goal of bringing industrial cooperation into this program over the next year should be a focus. This reviewer thought that more work should be concentrated on examining the durability of a superhard coating and in characterizing its structure more completely. The residual stress work will be critical to this set of studies. Another reviewer said the future research plan was logical and clear, but asked whether the team should look more at the role of the lubricant as well as substrate in the boundary film formation. A third reviewer said the plan is reasonably well laid out, and that further development of the internal strain measurement technique for very thin films is a significant contribution. Finally, a reviewer said that the future efforts planned are in the right direction for the further development and demonstration of thin, hard coatings technology as well as the ability to measure residual stresses and strains. These tools will be very beneficial when applied to the appropriate systems (i.e. rings and liners in engines, camshafts, gears, etc.)

Specific Strengths and Weaknesses (Written responses from 5 of 5 reviewers)

- Specific Strengths
  - These authors use the best available tools and continue to improve their product.
  - Strengths include solid results to date, establishment of an excellent infrastructure, and assembly of a talented and diverse team.
  - Very good industrial collaboration. Very good progress is being made in advancing the state of the art in this technology area.
  - Good combination of scientific understanding, new materials, and experimental work. Good collaboration. It appears that tech transfer will occur.
  - Seems to have developed wear resistant hard coatings. Has developed the initial stages of a technique to measure internal stress in thin films.
- Specific Weaknesses
  - No real weaknesses were apparent to this reviewer.
  - Not enough funding.
  - The characterization to date of the superhard coatings has been rather weak to date. Much more effort is required on microstructural and mechanical property studies.
  - Is the real mechanism of the friction reduction of superhard coatings known? Will the solution be robust beyond the test conditions? Is there a hysteresis on the friction coefficient? What happens with heat/cool and time delay cycling? Are the measures missing what is happening with the organic components of the lubricant and film?
  - Unclear if the lack of specificity in the presentation is due to confidentiality concerns or to lack of a clear vision of where the material development is going.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 5 reviewers)

- None.
- No additional recommendations or changes were noted.
- Send money.
- Fully understand mechanisms of friction coefficient reduction on sliding. Is it really related to chemical changes of substrate?

- Get a handle on running-in: it is obviously very slow and seems to involve some tribochemistry.

This category encompasses a number of advanced concepts to improve vehicle fuel efficiency, including truck accessory electrification, vehicle structure optimization, hybridization, and truck stop electrification. The goal of this category is to improve vehicle fuel efficiency by 10%. This category also contributes to the overall heavy vehicle systems optimization goal of increasing fuel efficiency by 25% by reduction in parasitic losses.

Below is a summary of average scores for 2006 for the ten projects in this category, along with the average, minimum, and maximum score for all projects in this report. The highest score in this category for each question is highlighted.

Summary of Scores for Projects in this Section

Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomp-lishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
30	*Advanced Brake Systems and Undercarriage Aerodynamics:* Glenn Grant, Pacific Northwest National Laboratory	3.33	3.33	2.33	2.67	3.00	2.93
31	*Advanced Electric Systems & Aerodynamics for Efficiency Improvements in Heavy Duty Trucks:* Kris Johnson, Caterpillar Inc.	3.67	3.67	**3.67**	3.20	3.25	3.49
33	*Analyzing Technologies to Reduce the Fuel Use of Heavy Vehicles:* Linda Gaines, Argonne National Laboratory **	**4.00**	3.50	3.50	**4.00**	3.50	3.70
34	*System Optimization of An Ultralight Electric Transit Bus:* Bruce Emmons, Autokinetics	**4.00**	3.80	3.60	3.80	**3.80**	**3.80**
36	*Truck Essential Power Systems Efficiency Improvements for Medium-Duty Trucks:* Larry Slone, Caterpillar Inc.	3.75	3.50	3.50	3.50	3.50	3.55
38	*21st Century Locomotive Technology:* Robert King, General Electric	3.75	3.75	**3.67**	**4.00**	3.75	3.78
40	*Advanced Hybrid Propulsion and Energy Management System for Mine Haul Trucks (Poster):* Tim Richter, General Electric **	3.50	3.50	3.00	2.50	3.00	3.10
41	*Diesel Fuel Reformer Technology Fuel Mixing (Poster):* Michael Krumpelt, Argonne National Laboratory **	3.00	3.00	3.00	**4.00**	3.00	3.20
42	*Plasma-Based Ion Mobility NOx Sensor (Poster):* Shuh-Haw Sheen, Argonne National Laboratory	3.67	**4.00**	**3.67**	3.67	3.67	3.73
44	*Regenerative Shocks/Tires (Poster):* John Hull, Argonne National Laboratory **	**4.00**	**4.00**	3.00	**4.00**	3.00	3.60
	Average Score for This Category	**3.70**	**3.65**	**3.41**	**3.50**	**3.46**	**3.54**

** = Projects with two or fewer reviewers.

Overall Program Scores

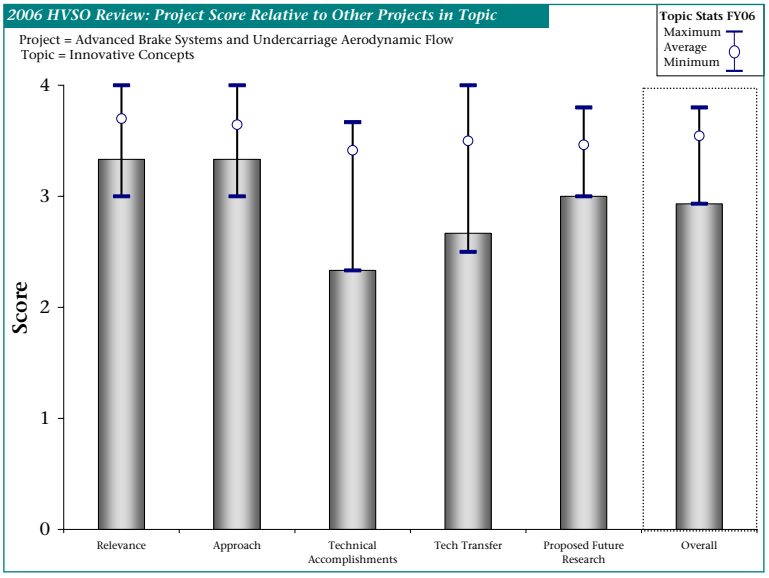
	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
Overall Program Average	3.52	3.51	3.25	3.27	3.24	3.36
Overall Program Maximum	4.00	4.00	4.00	4.00	4.00	4.00
Overall Program Minimum	2.00	2.67	2.33	2.00	2.43	2.60

Innovative Concepts

Advanced Brake Systems and Undercarriage Aerodynamics: Glenn Grant, Pacific Northwest National Laboratory

Brief Summary of Project

This project seeks to assess the potential of alternate disc brake system designs and technology concepts to improve energy efficiency, performance, and vehicle safety/stability. System and material optimization will lead to increased energy efficiency, reduced environmental impact, and improved life cycle costs.



Question 1: Relevance to overall DOE Objectives (Written responses from 2 of 3 reviewers)

One reviewer felt this project was relevant to the extent that the new proposed systems are lighter in weight. The other reviewer noted that brake performance is an important issue, especially if aerodynamic drag reducing efforts are successful.

Question 2: Approach to performing the research and development (Written responses from 2 of 3 reviewers)

A reviewer said this approach seems well reasoned, while another stated that the combination of numerics and experiments is rational.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 3 reviewers)

This group is well prepared for the next steps because they have been modeling their systems, felt one reviewer. Another reviewer's sense was that this project is "long" on qualitative and general considerations and "short" on specific contributions. Delivering air to the brake area is a subtle aspect of the aerodynamics problem. Many factors will influence the convective heat transfer. A CRADA to achieve solid results for one or more specific vehicle designs could give guidance of a "how to" nature for other OEMs, according to this reviewer.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 3 reviewers)

A reviewer said that the tech transfer aspects of this project were limited, but may be adequate. Another said that apparently, this is in the planning phase.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 3 reviewers)

The only comment received was that the plans for future research are rational.

Specific Strengths and Weaknesses (Written responses from 1 of 3 reviewers)

- Specific Strengths
  - The group seems to think in terms of material properties rather than simple testing of available materials.
- Specific Weaknesses
  - None stated by reviewers.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 0 of 3 reviewers)

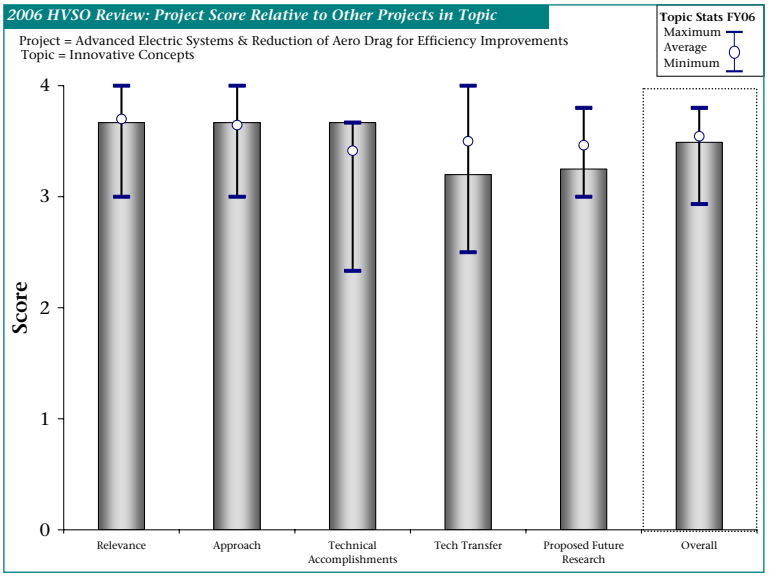
- No reviewers offered specific recommendations.

Innovative Concepts

Advanced Electric Systems & Aerodynamics for Efficiency Improvements in Heavy Duty Trucks: Kris Johnson, Caterpillar Inc.

Brief Summary of Project

This project team is seeking to improve the fuel efficiency of heavy-duty trucks through improvements in cooling system performance, air system management, and advanced power management. This project builds on the technology base from the Caterpillar MorElectric Truck.



Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 6 reviewers)

Review comments on this aspect of the research were positive. The first reviewer felt that the project meets 21CTP objectives for engine performance improvements. A second noted that this is a well constructed project and it presents a quite rational systems approach to overall energy efficiency. Evaluation of commercial value of technology is good, noted a reviewer, who also felt that looking at the whole system is good. This reviewer said that the research team has made good use of CFD to direct hardware production and system integration. Strong relevance to supporting the objective of improved fuel economy, said another reviewer. Finally, a reviewer stated that addressing air conditioning, mild hybridization, air compressor energy demand and cooling system efficiency deals with some of the highest priority challenges to improving truck fuel efficiency. Addressing cooling efficiency is critically important in the face of increased cooling demands posed by the EGR equipment required under 2007 emissions rules.

Question 2: Approach to performing the research and development (Written responses from 5 of 6 reviewers)

Reviewers felt the approach was logical and well-integrated. A reviewer said that the Caterpillar program is a good attempt to transcend the parasitic losses of engine-based consumers. Another felt the sequence of efforts is quite logical. A reviewer noted the good interaction with David Pointer from Argonne National Laboratory on the frontal shape drag of the vehicle, and felt that the team had a good integrated approach and also that development and testing is great. The team has a good total systems approach to achieving potential fuel economy improvements, in another reviewer's opinion. A final reviewer said that all aspects of the R&D project appear outstanding. The project very effectively addresses the highest priority efficiency issues in areas where technical accomplishments are possible, and draws upon other research through partnerships and use of non-Caterpillar technologies.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 6 reviewers)

Review comments here were generally positive as well. If the program reaches full integration into industry, significant improvements will be derived, said one reviewer. The project appears to be on-track and making good progress, said another. A reviewer pointed out that real hardware has been produced and demonstrated, and that there is very good potential for energy savings. The team has made a good start incorporating various components into a vehicle, offered a reviewer. The project team has completed the component and subsystem work necessary to complete vehicle system integration on schedule, said the final reviewer.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 6 reviewers)

Review comments varied here, but were generally positive. One felt that there was excellent collaboration with industrial suppliers. Another said that coordination with Argonne was good, and that there was no need for other industry collaboration. On the other hand, a reviewer noted that this was possibly not an applicable question in some regards, as the final product would be a Caterpillar-specific technology (along with Caterpillar system suppliers). Finally, a reviewer offered that Caterpillar has implemented its hardware developments as producible items. This is only one step short of complete success, which would be high commercial sales volume for its market.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 6 reviewers)

Most review comments were positive. One said that continuation along the same path is clearly advisable. A reviewer said that the research team had a good plan for completion of the stated goals in a timely manner. The project expands on the technically successful Caterpillar MorElectric program, noted a third reviewer, who continued by saying that the focus on hybridization offers hope for truck designs that greatly minimize idle fuel consumption and emissions. On the other hand, a reviewer said that the program seems well focused, and offers good potential, but this reviewer did not see specific commercialization plans. A reviewer thought that the presentation indicates that research and deployment will continue, but no future plan was listed. A final reviewer simply said that the future research plan was not described.

Specific Strengths and Weaknesses (Written responses from 4 of 6 reviewers)

- Specific Strengths
  - Potential for significant contributions.
  - Actual hardware and demonstration, very good potential for energy savings.
  - Total system approach to improving fuel economy.
  - Very strong system engineer[ing], not just reduction to practice, but implementation as producible hardware. Caterpillar is making hardware that can be sold commercially.
- Specific Weaknesses
  - I don't really see any, but my area of expertise is not electrification.
  - 20 kW electric fan motor may not be able to meet complete cooling requirements. Will be interested to see results for the cooling module under various engine loadings.
  - Caterpillar hasn't been successful in actually selling MorElectric hardware to the trucking industry, even though the equipment is widely admired and understood to offer major technical advantages. It's unclear how this situation will be corrected in this program. The benefits of this excellent work will only be attained if the equipment actually enters the market.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 6 reviewers)

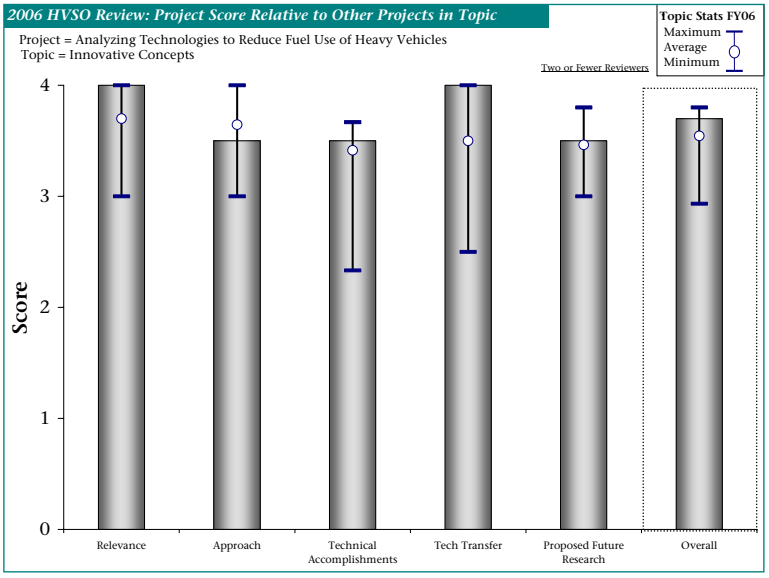
- Provide updated info on field testing and units currently in use.
- None.
- None.

Innovative Concepts

Analyzing Technologies to Reduce the Fuel Use of Heavy Vehicles: Linda Gaines, Argonne National Laboratory

Brief Summary of Project

Argonne is providing scientific evaluations, using analytical techniques, of technologies to increase fuel efficiency and reduce emissions of heavy vehicles. Idling reduction is a key focus of this activity.



Question 1: Relevance to overall DOE Objectives (Written responses from 1 of 2 reviewers)

The commenting reviewer said that this program addresses well the need for reduction of petroleum demand and diesel emissions for idling heavy vehicles.

Question 2: Approach to performing the research and development (Written responses from 2 of 2 reviewers)

Reviewer comments were both positive for this aspect of the project. An excellent job dealing with myriad complex issues, said the first reviewer. Good approach combining the need to look at problem from technical as well as regulatory standpoint, said the second.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 1 of 2 reviewers)

The sole commenting reviewer singled out the good progress in identifying state and local regulations as well as in identifying potential technical solutions to the problem of idling reduction.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 1 of 2 reviewers)

Good collaboration with industry and other governmental agencies in identifying issues and technology solutions, said a reviewer, who also noted the excellent communication of findings at key technical conferences such as the Diesel Engine Emission Reduction Conference and the SAE Commercial Vehicle Engineering Congress and Expo.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 2 reviewers)

The reviewer said that the presenters had a good plan to look at the economics of technical solutions as well as looking at workday idling and total fuel cycle impacts.

Specific Strengths and Weaknesses (Written responses from 2 of 2 reviewers)

- Specific Strengths
  - Targets current and future concerns. Takes an extensive systems approach. Good delineation of tradeoffs.
  - Definition of the problem of idling reduction, good collaboration with industry, good communication ot technical results and pending state and local legislation.
- Specific Weaknesses
  - None stated by reviewers.

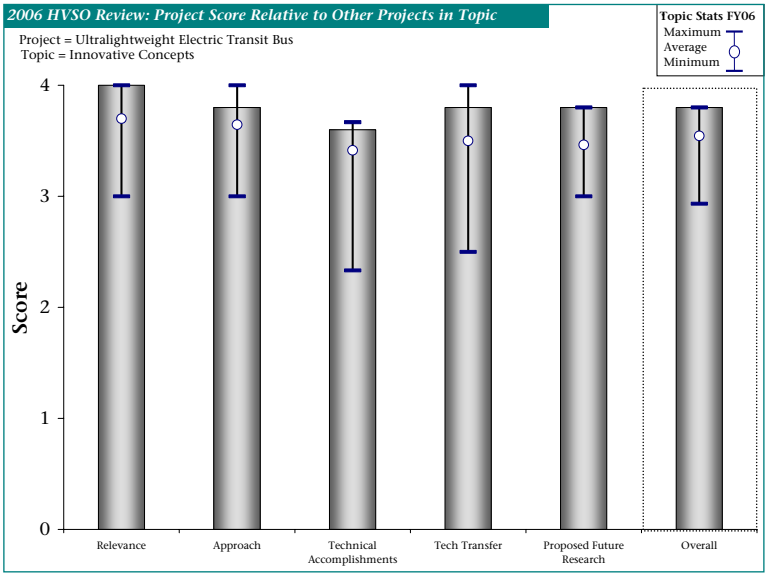
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 0 of 2 reviewers)

- None offered by reviewers.

Innovative Concepts

System Optimization of An Ultralight Electric Transit Bus: Bruce Emmons, Autokinetics

Brief Summary of Project



Autokinetics is developing a full-size transit bus using lightweight stainless steel to achieve significant fuel economy benefits relative to conventional transit buses. In this project, the project team is developing an advanced electric drive propulsion system optimized for maximum fuel economy.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 5 reviewers)

Reviewers felt that the project has direct relevance to the improvement of fuel economy, and a 60% fuel improvement in urban bus is impressive. Another reviewer felt that this project is unusual for addressing structural weight from an overall systems viewpoint, instead of one or several subsystems. A reviewer observed that the bus market represents 2500 new sales per year here and tens of thousands around the world, all with the potential to be far more energy efficient, and gave the project the highest rating. Finally, a reviewer stated that this subject area is not in his area of expertise. However, as a concerned and a technically-aware taxpaying citizen, this reviewer was pleased to see that DOE funds are channeled to this innovative and competently executed effort. It will be especially valuable if their sales to China meet expectations and serve to address the balance of payments.

Question 2: Approach to performing the research and development (Written responses from 4 of 5 reviewers)

First, a reviewer said that "it all makes sense." A second reviewer said that the approach combines practicality with expert knowledge of material, forming and fabrication. The problem was analyzed from a fundamental standpoint, and then addressed with a practically-grounded new approach. Thirdly, a reviewer commented that this was an excellent approach incorporating lightweight structure, an electric drivetrain propulsion system, and optimization of subsystems to improve fuel economy. A technology demonstrator is an excellent way to show benefits. Lastly, a reviewer believed that, given the financial constraints on the effort, the approach has been balanced very well. This reviewer heartily endorsed the approach of actually building a fully integrated bus. If it were somehow possible, this reviewer would like to see more analysis done on the economics of the new bus.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 5 reviewers)

The project has demonstrated exceptional weight reduction in a design approach which can be applied to other vehicles, in the first reviewer's opinion. A reviewer observed that the project appears to be on-track. Another reviewer said that given the level of funding, the accomplishments to date have been nothing short of remarkable. Per dollar spent, this project is among the very best in the program in terms of accomplishments. A reviewer pointed out that there has been good progress on design and selection of components, and that fabrication of chassis and some components is underway. A final reviewer wondered if propulsion unit costs may be too high.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 5 reviewers)

Autokinetics is making very good use of its industrial partners, noted one reviewer. Another felt that the project team's outreach is exemplary. Great list of collaborators, noted a third reviewer, who thought it was not clear whether or not a commercial company will license and run with this. A reviewer expressed the similar opinion

that the project had outstanding collaboration with a large number of industrial suppliers, partners, and technical advisors: this reviewer said this was the best overall of the group of the projects reviewed. The final reviewer said that the reported death in the Chinese firm was unfortunate, but the ties in place will doubtless produce the needed industrial support.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 5 reviewers)

Demonstration of the completed bus this year will be important to validating the structural design concept, observed a reviewer. Reviewers said that the project was on track, and had a good plan and timeline to completion of the technology demonstrator vehicle. The last reviewer agreed fully with the stated plans. In the presentation, side impact simulations were presented and the system for limiting damage from a front-impact was discussed. It would seem that simulated examination of a rear-end collision could be included. Some expensive and very much needed equipment is suspended beneath the rear passenger seats.

Specific Strengths and Weaknesses (Written responses from 4 of 5 reviewers)

- Specific Strengths
  - This project will provide a working example of a practical use of stainless steel for major weight reduction in heavy vehicles. There are significant implications for military trucks, which have a strong need for increased payload-to weight, or the ability to carry current payloads plus armor protection.
  - Outstanding engineering effort with excellent integration of modeling with construction of the actual bus. The effort on the frame has been especially strong.
  - Great technology demonstrator.
  - Well thought out plan to develop a technology demonstrator hybrid bus. Excellent collaboration of industry, universities, and laboratories.
- Specific Weaknesses
  - None.
  - Given the level of effort and funding, I'm loathe to identify any weakness. If funding and manpower were to allow for it, I would like to see further economic analyses being made and stronger ties forged with bus manufacturers.
  - Lacks funds for full prove-out and field endurance testing.
  - Modeling for maintenance and operational costs.

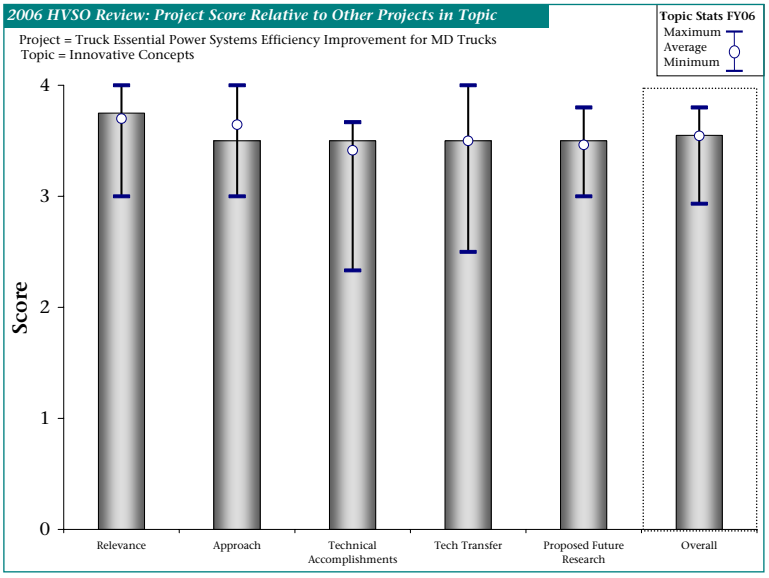
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 5 reviewers)

- Once the bus is demonstrated, there should be an intensive technology transfer effort to implement the design-in-stainless practices illustrated by this bus. Analyses should be done to see if this structural design system can be applied to commercial truck bodies and trailer chassis.
- Perhaps examine more closely rear impact damage.
- Modeling for maintenance and operational costs.

Innovative Concepts

Truck Essential Power Systems Efficiency Improvements for Medium-Duty Trucks: Larry Slone, Caterpillar Inc.

Brief Summary of Project



Caterpillar is developing technologies in this project to improve the efficiency of a medium-duty truck through truck electrification. Among the onboard systems to be electrified are the power steering and vehicle cooling systems, along with provision for electric power for truck-mounted accessories such as utility truck booms.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 4 reviewers)

The review comments on the project relevance were favorable. The project addresses a collection of individual efficiency improvements that are high priority, technically feasible, and offer eventual customer benefits such as reduced fuel consumption and maintenance, better reliability, and improved functionality. Another commenter noted that this project addresses energy efficiency for medium duty trucks, and the potential fuel savings clearly justify the DOE investment in this program. Finally, a reviewer said this project had a good tie-in to the fuel economy improvement objective of the overall 21CTP program.

Question 2: Approach to performing the research and development (Written responses from 3 of 4 reviewers)

The first reviewer thought that Caterpillar is making very effective use of partner technologies, and focusing on customer needs in order to assure market acceptance of the technologies, and thought that the program schedule is fast but realistic. A second reviewer said that this is a well considered effort that will represent "good value for (US taxpayers) money." Their approach is rational and clearly well thought through. The last reviewer said that the team had an excellent total systems approach to achieving fuel economy improvements.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 4 reviewers)

The project has made rapid progress, noted the first reviewer. A second reviewer noted that the presenter's slides covered these aspects very thoroughly and rationally. Thirdly, a reviewer noted the very good test plan and setup, and that the program builds on work of the previous program in this area.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 4 reviewers)

Reviews here were favorable as well. Caterpillar's industrial partnerships bring in additional experience with implementing their respective technologies, and will enhance the effectiveness of work done by the partners on future truck efficiency work, whether with or without Caterpillar. The team is as broad as it needs to be, said a second reviewer. The last reviewer noted the excellent industry collaboration.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 4 reviewers)

A reviewer noted that the future work is to apply and test the work to-date. Another pointed out the good plan and timeline for achieving future objectives.

Specific Strengths and Weaknesses (Written responses from 3 of 4 reviewers)

- Specific Strengths
  - Very good industry partnerships. Well-chosen technologies for overall effect on truck efficiency, feasibility and potential customer acceptance, plus very good integration.
  - Well organized.
  - Overall total systems approach to improving fuel economy by reducing parasitic losses.
- Specific Weaknesses
  - None.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 4 reviewers)

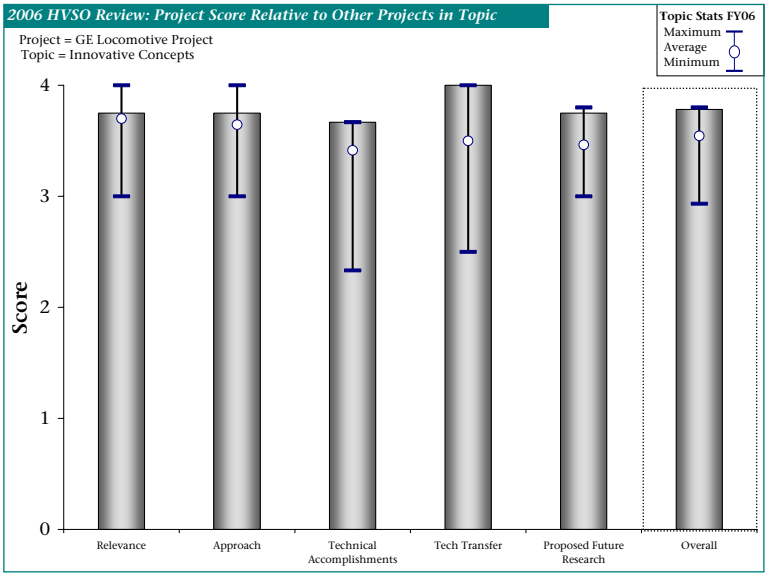
- None.

Innovative Concepts

21st Century Locomotive Technology: Robert King, General Electric

Brief Summary of Project

This project is focused on reducing fuel use of rail locomotives by 15-20% through capturing and storing regenerative braking energy and through fuel optimization control (route, terrain, and train characteristics).



Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 4 reviewers)

Comments on this aspect of research were quite good. From the first reviewer: an efficient rail industry is essential to the national economy and may reduce fuel consumption in the trucking industry by attracting some of its business. Conversely, if rail doesn't improve its fuel economy in step with trucking, it may lose some business. This project is developing products to significantly improve locomotive fuel economy. The second reviewer said that this will be a very short review because the project is "nearly perfect," with important tasks tackled intelligently and supported appropriately by an industrial leader. The final review comment was that this is a good project to improve fuel economy of locomotives.

Question 2: Approach to performing the research and development (Written responses from 3 of 4 reviewers)

Approach comments were favorable. The first comment was that the project has feasible technology goals with significant fuel economy payoffs, and the approach is practical and well-prioritized. No significant improvement seems to be possible in another reviewer's opinion. Lastly, a reviewer thought that this project had a good approach to fuel improvement goal by optimizing fuel cycle based on drive route.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 4 reviewers)

Technical accomplishments were felt to be good as well. First, the project is meeting its technical objectives on schedule. A second reviewer noted that the project had great results to date from an outstanding suite of efforts, from modeling to experiment to track testing. The third reviewer said that good progress has been made on selecting hybrid battery technology and the demonstration of the trip optimizer.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 4 reviewers)

Review comments were short, but generally positive. A reviewer said that the technical effort appears fully integrated with the commercialization effort. Another said that the project has good industry collaboration. A third reviewer characterized the tech transfer as "perfect". A final reviewer thought that DOE's contribution wasn't clear.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 4 reviewers)

The initial review comment was that the future effort will implement the hybrid electric locomotive design and, if fully successful, yield the biggest fuel savings of the program. The work to date indicates that the future technical goals will be met. Another noted that there was a good plan for hybrid test track demonstration integrating fuel optimization controls. A reviewer said that clearly the work must focus next, as is proposed, on the batteries.

Specific Strengths and Weaknesses (Written responses from 4 of 4 reviewers)

- Specific Strengths
  - Too many to bother to list.
  - Highly practical approach which targets high-priority achievable goals for increasing locomotive fuel economy.
  - Clear connection from research to application. Developing technologies that can be used at many other industries.
  - Fuel optimizer methodology.
- Specific Weaknesses
  - None apparent.
  - None.
  - Transfer of results to other applications?

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 4 reviewers)

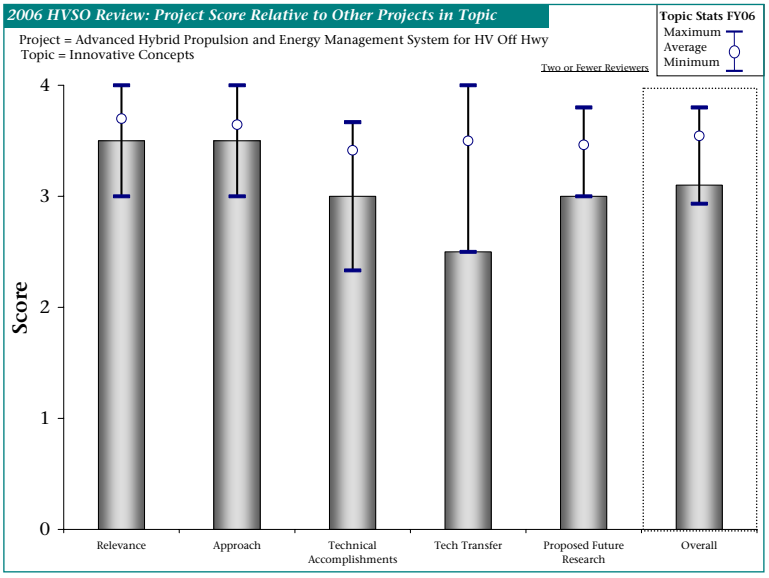
- None.
- The only possible addition to recommend would be extra funding should it be required. This program is ideal and provides DOE with just the kind of success it needs to demonstrate.

Innovative Concepts

Advanced Hybrid Propulsion and Energy Management System for Mine Haul Trucks (Poster): Tim Richter, General Electric

Brief Summary of Project

In this project, the team will design, build, and validate a diesel-electric mining off-highway vehicle with a hybrid energy storage system to recover braking energy and use this energy for useful work, thus reducing fuel consumption. The off-highway truck being examined for this project has a loaded weight of approximately 850,000 pounds.



Question 1: Relevance to overall DOE Objectives (Written responses from 1 of 2 reviewers)

A reviewer said that the program addresses fuel savings and reduction in emissions.

Question 2: Approach to performing the research and development (Written responses from 1 of 2 reviewers)

The commenting reviewer felt that a technology demonstrator is a good way to show potential improvements using a hybrid approach.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 1 of 2 reviewers)

This reviewer said that good progress was made on achieving the stated goals of the demonstrator project.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 1 of 2 reviewers)

Some coordination has been undertaken with other industry companies, in the only commenting reviewer's opinion.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 2 reviewers)

The reviewer suggested that the future work plan should continue to work towards objectives of showing benefits of hybrid strategy.

Specific Strengths and Weaknesses (Written responses from 1 of 2 reviewers)

- Specific Strengths
  - Technology demonstrator approach to showing benefits of hybrid propulsion system.
- Specific Weaknesses
  - Limited details of research provided; a clearer action plan needs to be communicated.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 2 reviewers)

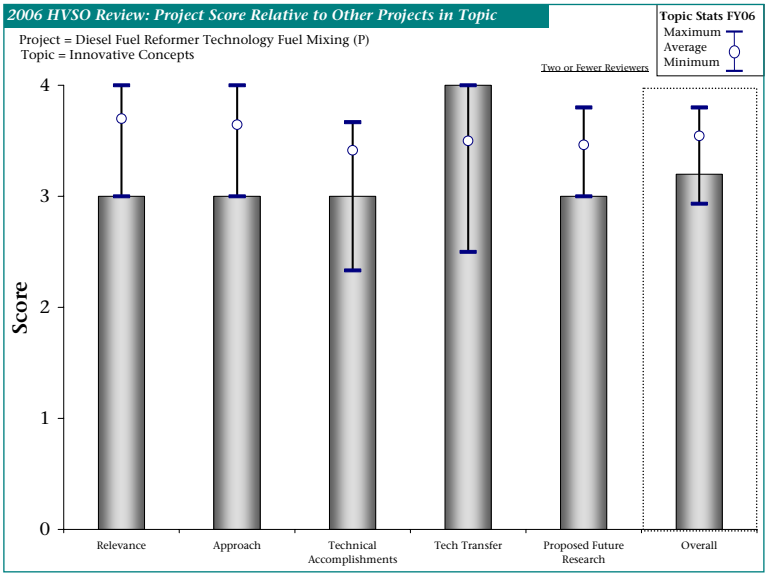
- Use quad chart to communicate overall project objectives. Better communication of timeline, future goals in poster presentation.

Innovative Concepts

Diesel Fuel Reformer Technology Fuel Mixing (Poster): Michael Krumpelt, Argonne National Laboratory

Brief Summary of Project

The objective of this project is to develop an auxiliary power unit (APU) based on an autothermal reforming process to convert diesel fuel into hydrogen-rich gas onboard a heavy-duty vehicle. Initial research has focused on improving the fuel evaporation within the reformer to improve performance and prevent coke formation on the catalyst.



Question 1: Relevance to overall DOE Objectives (Written responses from 1 of 1 reviewers)

The only reviewer commented that there was a good tie-in with this project to fuel economy improvements and emissions reduction goals.

Question 2: Approach to performing the research and development (Written responses from 1 of 1 reviewers)

Good laboratory approach to examine key technical issues for diesel reformer, the reviewer offered. The size of the APU will need to be scaled up to have meaningful industrial applications.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 1 of 1 reviewers)

Good initial progress towards understanding of how the reformer works and can be monitored as well as observation of cool flame, noted the only reviewer.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 1 of 1 reviewers)

The only comment received was that there was excellent industrial collaboration on the project.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 1 reviewers)

The sole reviewer said that there was a good plan going forward for experimental work.

Specific Strengths and Weaknesses (Written responses from 1 of 1 reviewers)

- Specific Strengths
  - Relevant topic, good experimental plan.
- Specific Weaknesses
  - Size of APU is small. Good for lab measurements, but needs to be scaled up to be practical.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 1 reviewers)

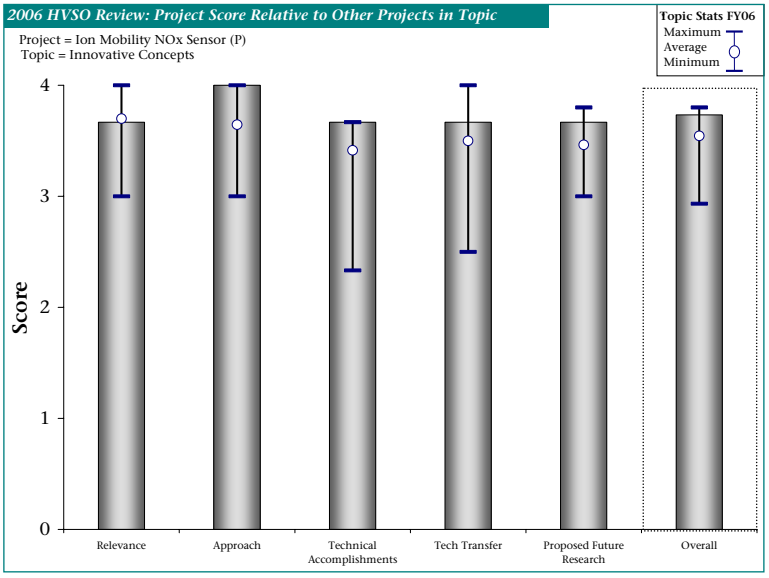
- Look at follow-on work of scaling up results to full-size prototype for a heavy truck application.

Innovative Concepts

Plasma-Based Ion Mobility NOx Sensor (Poster): Shuh-Haw Sheen, Argonne National Laboratory

Brief Summary of Project

This team is developing a fast-response low-cost NOx sensor based on ion-mobility measurements for heavy-duty vehicle combustion and emission control. This sensor needs to provide real-time sensing of NOx in exhaust gases while maintaining good durability.



Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 3 reviewers)

A first reviewer offered that the relevance appears to be more related to emissions control than to vehicle efficiency. Having said this, it is also clear that a low-cost, durable NOx sensor that permits feedback control of engine parameters affecting NOx output may allow active control and minimization of NOx output, leading to a less burdensome aftertreatment package and presumably greater engine efficiency. A second reviewer said that NOx emissions are already a critical consideration for combustion systems and they will undoubtedly become more so over time. Given the size and scope of the DOE program, allocating a small fraction of the total funding toward this goal seems to be both prudent and politic. The final reviewer noted that the project has direct focus on a key technical barrier to reducing NOx emissions: monitoring the NOx emissions during different driving scenarios.

Question 2: Approach to performing the research and development (Written responses from 3 of 3 reviewers)

Review comments on the approach were generally positive. First, the approach is extremely innovative and practical. It looks like a strong candidate for reduction to an inexpensive and highly producible design that will provide accurate and quick measurements. Second, the emphasis on producing a durable, low-cost device is appropriate and the choices made appear to have been correct. Finally, a reviewer said that the team has an excellent technical approach and plan.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 3 reviewers)

The first review comment was that the project has clearly demonstrated the principle of operation in a prototype configuration that lends high confidence that a practical production device can be developed. A reviewer pointed out that a functioning device has been built, important data have been collected, many questions have been answered authoritatively, and key challenges have been identified. Overall, this is an outstanding effort, according to this reviewer. Finally, a reviewer said that good progress has been made on identifying other gases which may limit ability to detect NOx in exhaust stream.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 3 reviewers)

First, a reviewer noted that the research team is working with Cummins, and engine OEM with a clear use for a NOx sensor. This was also seen in a second reviewer's comment specifically that Cummins participation is critical to this project and it is heartening to see that the firm has provided at least some financial support for the work. One clearly hopes to see stronger industrial buy-in in the near term. This project has an excellent industry collaboration on practical aspects of NOx sensor, according to the last reviewer.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 3 reviewers)

Future work appears to directly address steps needed to promptly move the technology toward commercial application as quickly as practical, the first reviewer offered. Another reviewer very much admired the design of the test matrix and the manner in which it leads to a single decision, go or no-go. This approach is exactly correct. Lastly, a reviewer said the team has a good plan to focus on water vapor effects on the ability to monitor NOx with this sensor.

Specific Strengths and Weaknesses (Written responses from 3 of 3 reviewers)

- Specific Strengths
  - The researchers appreciate the need for practical application, and focus their research accordingly.
  - Outstanding expertise in device design and prototype fabrication has been coupled with excellent understanding of the problem to be addressed. The environmental testing program should be excellent.
  - Good project objectives, plan, and experimental approach.
- Specific Weaknesses
  - None evident.
  - At this stage no serious weakness is apparent. If the decision to go forward is made, then significant industrial support must be elicited.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 3 reviewers)

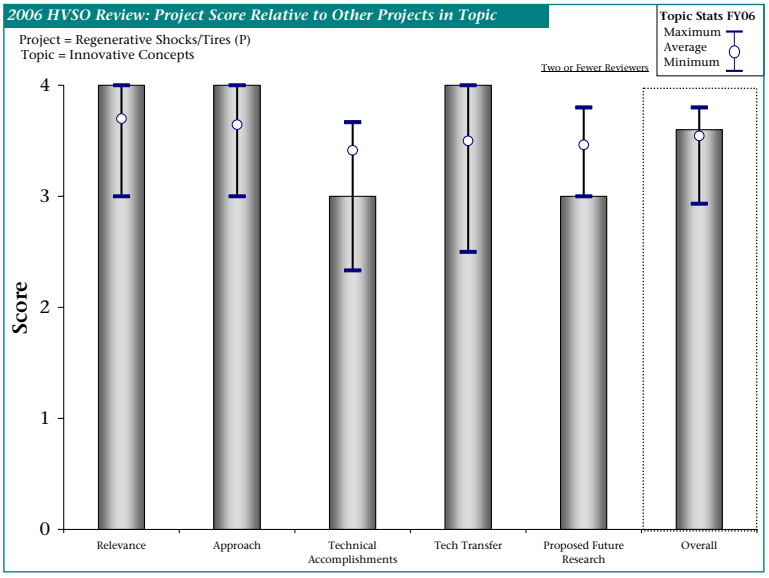
- None.
- None.

Innovative Concepts

Regenerative Shocks/Tires (Poster): John Hull, Argonne National Laboratory

Brief Summary of Project

The concept of this project is to reclaim the vertical motion of shock absorbers and the deformation and vertical motion of rolling tires as useful work energy for vehicle propulsion instead of dissipating it as heat.



Question 1: Relevance to overall DOE Objectives (Written responses from 1 of 1 reviewers)

The only reviewer felt the project was a "real sleeper" that is well worth doing and is a perfect example of where DOE should be investing.

Question 2: Approach to performing the research and development (Written responses from 0 of 1 reviewers)

The only reviewer did not provide written comments related to the research and development approach.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 0 of 1 reviewers)

The reviewer did not offer any written comments on the technical accomplishments of this project.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 1 of 1 reviewers)

Planning for a CRADA makes the effort very credible, noted the reviewer.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 1 reviewers)

The reviewer suggested that the project team check with the truck seating manufacturers who have road roughness profiles to help them design air-ride seats.

Specific Strengths and Weaknesses (Written responses from 0 of 1 reviewers)

- Specific Strengths
  - None provided.
- Specific Weaknesses
  - None noted.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 1 reviewers)

- Would the air bags used in air ride trailers and tractor seats be a source of power equivalent to shock absorbers?

In the thermal control arena, projects are contributing to a goal of reducing the size of truck radiators by 10%, leading to a 5% increase in fuel economy. This will be done through more efficient cooling systems, advanced nanofluid coolants, and improved underhood design through modeling. This category also contributes to the overall heavy vehicle systems optimization goal of increasing fuel efficiency by 25% by reduction in parasitic losses.

Below is a summary of average scores for 2006 for the six projects in this category, along with the average, minimum, and maximum score for all projects in this report. The highest score in this category for each question is highlighted.

Summary of Scores for Projects in this Section

Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomp-lishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
46	*CFD and Thermo-Fluid Systems Modeling for Underhood Thermal Analysis:* Tanju Sofu, Argonne National Laboratory	3.33	3.33	3.33	3.67	3.00	3.33
48	*Effects of Nanofluids on Heavy Vehicle Systems:* Dileep Singh, Argonne National Laboratory	2.80	2.80	2.60	2.00	2.80	2.60
50	*Efficient Cooling in Engines with Nucleated Boiling:* Dave France, Argonne National Laboratory	3.50	3.75	3.50	2.50	2.75	3.20
52	*Nanofluids for Improved Efficiency in Cooling Systems:* Steve Choi, Argonne National Laboratory	3.50	2.67	2.33	2.67	2.67	2.77
55	*Overview of Thermal Control Program at Argonne:* John Hull, Argonne National Laboratory **	4.00	4.00	4.00	4.00	4.00	4.00
57	*Nanofluid Critical Heat Flux (Poster):* Steve Choi, Argonne National Laboratory **	2.00	4.00	3.00	2.00	3.00	2.80
	Average Score for This Category	**3.25**	**3.15**	**2.90**	**2.68**	**2.85**	**2.97**

** = Projects with two or fewer reviewers.

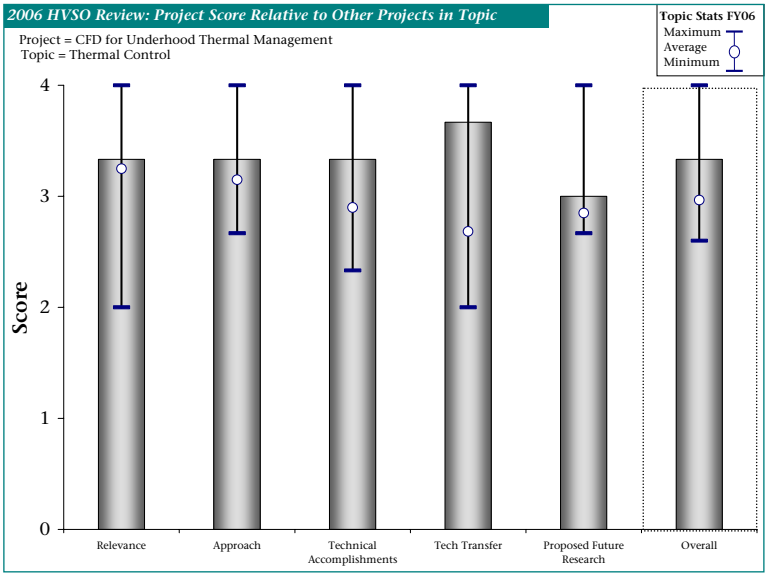
Overall Program Scores

	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
Overall Program Average	3.52	3.51	3.25	3.27	3.24	3.36
Overall Program Maximum	4.00	4.00	4.00	4.00	4.00	4.00
Overall Program Minimum	2.00	2.67	2.33	2.00	2.43	2.60

Thermal Control

CFD and Thermo-Fluid Systems Modeling for Underhood Thermal Analysis: Tanju Sofu, Argonne National Laboratory

Brief Summary of Project



These investigators are working toward development of an integrated thermal analysis capability to help OEMs design more energy efficient vehicles with acceptable underhood temperatures. Determination of accurate temperature distributions in an engine allows redesign of the underhood configuration and helps achieve fuel efficiencies through cooling system optimization and radiator size reduction.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 3 reviewers)

In one reviewer's opinion, this program takes an overall thermal control approach and addresses key areas of higher energy efficiency, reduced emissions, and reduction of parasitic losses. This was an excellent presentation, said another: very straightforward with clear relevance to the heavy vehicle program objectives, albeit in support of the overall design objectives and not of "aerodynamic drag." A reviewer offered that it was too bad this wasn't started years ago.

Question 2: Approach to performing the research and development (Written responses from 2 of 3 reviewers)

The first reviwer commented that the current effort builds upon Caterpillar work for the Cummins CRADA. The approach of "combined models" is quite rational, this reviewer continued. The combination of 3D and 1D modeling is a good approach to solving the computational challenges, said the other reviewer: planned use of experimental data to verify models is a plus.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 3 reviewers)

Both reviewers were generally positive on this aspect of research. The first said that very good overall progress is indicated. Their approach can be adopted by others. The second noted that the project started recently, but used information from a previous CRADA with Caterpillar to build the project plan. This will give this program a head start to success, in this reviewer's view.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 3 reviewers)

The first reviewer simply stated the project was of obvious value to Caterpillar and Cummins. The second said that an excellent industry/lab plan was in place. Argonne will provide computational modeling and hardware for simulation. Cummins will verify models through experimental testing.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 3 reviewers)

Plans are well formulated, said the first reviewer. The other offered that the plan to develop detailed models of cooling module heat exchangers and prime movers such as fans will be key to providing meaningful simulations.

Specific Strengths and Weaknesses (Written responses from 1 of 3 reviewers)

- Specific Strengths
  - Overall thermal modeling and control approach. Excellent industry/lab collaboration.
- Specific Weaknesses
  - None offered by reviewers.

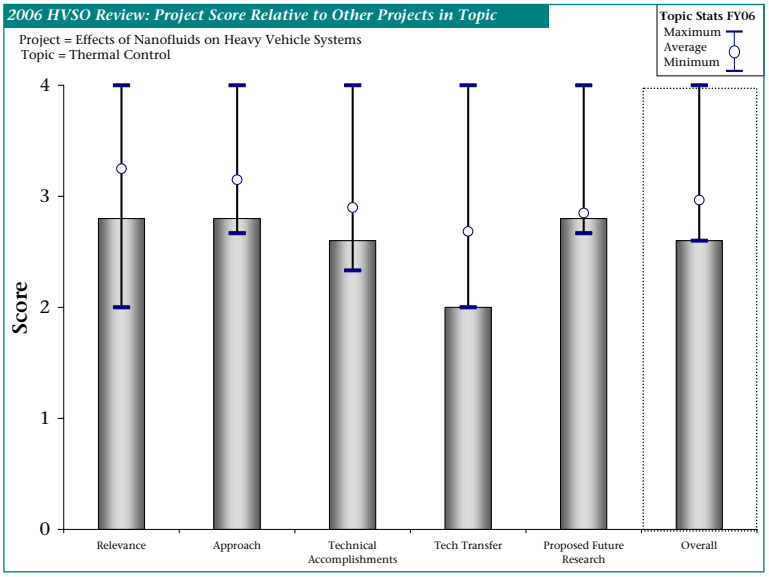
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 3 reviewers)

- Consider using 1D code called KULI to model cooling module in combination with already chosen Flowmaster and Fluent software. Use MRF fan module with properly chosen volume sweep to model fan in CFD.

Thermal Control

Effects of Nanofluids on Heavy Vehicle Systems: Dileep Singh, Argonne National Laboratory

Brief Summary of Project



The overall goal of this project is to demonstrate the viability of nanofluids for heavy vehicle radiator systems. Nanofluids are a new class of heat transfer fluids engineered by dispersing very small (nanometer-scale) particles in traditional fluids. Among the tests being conducted in this work is an analysis of the erosive effects of nanofluids on radiator materials.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 5 reviewers)

A reviewer said that cooling system advances that lead to reduction in radiator size can lead to huge energy savings: use of nanofluids is one possible means by which radiators can be significantly reduced in size. On the other hand, a reviewer said that the project is relevant if the "mother" project on using nanofluids for cooling is successful. At this point that is in doubt, at least in this reviewer's mind. This was echoed in another's comment that the project assumes that nanoparticles will be used in a fleet application. If this assumption is not accepted, the "relevance" cannot be judged larger than 2 out of 4 in this scoring system. Another commented that the constraints of advanced fluids need to be evaluated to determine if nanofluids can help benefit energy efficiency and reduce parasitic losses. Finally, a reviewer said that it seems that much more needs to be understood about the behavior of nanoparticles in fluids before questions about the erosive effects or wear effects can be properly addressed. It might be natural to assume that erosion might be a big concern, but it may not be an issue at all if nanoparticles are maintained at their very small size.

Question 2: Approach to performing the research and development (Written responses from 5 of 5 reviewers)

The first reviewer offered detailed comments regarding this project. This effort is the critical one (according to the reviewer) for determining just how effective nanofluids may be in truck cooling systems. The examination of frictional effects, while interesting, should not be a primary focus. This reviewer would prefer to see two efforts added to this work. First is consideration of pumping systems. As was brought out in the questions, pumps see higher fluid velocities, and perhaps that is where most of the wear might be expected. Second is closer examination of possible effects of corrosion combined with erosion. As a matter of course fluid conductivities should be measured and the compositions of spent fluids should be analyzed. Another reviewer indicated that the team had an excellent technical approach to determine erosion characteristics as well as wear and friction. Another reviewer said that the erosion testing is well thought out, though not much has come of it. The "lubrication" by nanofluids lacks any justification. The next reviewer indicated that although a slide showed the experimental apparatus used, the details were not made apparent. Does the jet discharge into a submerged environment? If not, the experiment has no meaning for a radiator. Submerged "jet erosion" could be avoided at the inlet to the radiator. The presentation made a "strong" focus on a "small potential problem." The relevance of "ball-on-disk" was not apparent. It is probably premature to be designing erosion test methods, thought the last reviewer.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 5 reviewers)

Good progress to date establishing baselines and initial work on copper nanofluid erosion study, noted the first reviewer. The second reviewer said that the system that was built appears to yield good data and the results to date are quite promising. This reviewer would prefer to see results from other fluids now, rather than the next set from

the current fluid. (This is to say that perhaps 1200 hours is enough for the currently running test.) A reviewer said that accomplishments were very limited, but in the defense of the team, it has taken time to build the equipment. The data created may have value for some application, said a reviewer, who felt that these data do not seem relevant to the heavy vehicle program. Finally, a reviewer said that the results obtained thus far may not have any impact on the real problems facing this technology.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 5 reviewers)

First, a reviewer said that the rating for this project is tied to the rating for Dr. Choi's project on nanofluids. Interactions with industry have been extensive to date, but it is imperative to obtain some significant buy-in soon. Given the other concerns, this question of technology transfer is a small problem, said the second reviewer. The third reviewer suggested that the team consider direct interaction with a pump manufacturer and a radiator manufacturer to discuss results, and look to present information in appropriate technical journals for tech transfer. A reviewer thought the team needs to collaborate in the more fundamental aspects of nanoparticle behavior research. A final reviewer said that judging technology transfer was probably too early at this stage.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 5 reviewers)

The first reviewer said that a good plan has been established to complete future work. A reviewer said that the plans are solid, with the exception of not looking at pumps and not examining possible effects of corrosion more closely. Some of the erosion work could be useful, thought another reviewer, and said the tribology tests need some clever selection of fluids and particulates to be tested and a good look at the literature.

Specific Strengths and Weaknesses (Written responses from 4 of 5 reviewers)

- Specific Strengths
  - Excellent test plan and set up.
  - Couples to strong ANL expertise in nanofluids; good equipment and capable researchers; emphasis on industrially relevant concerns.
  - Erosion equipment may be useful for other work. Erosion work will need to be done if any successful nanofluid-based coolants are developed, but not until that time.
  - Not really much that represents an appropriate strength.
- Specific Weaknesses
  - There is a clear need to settle on a specific nanofluid for appropriate reasons and then work with it. Perhaps the copper system is correct, but the team must make the case for why it is the leading candidate.
  - Tribology tests do not make a useful contribution at this point.
  - Lack of direct collaboration with industrial partners.
  - Even though research in this area has been ongoing for some time, it may be premature to be supporting these kinds of test developments.

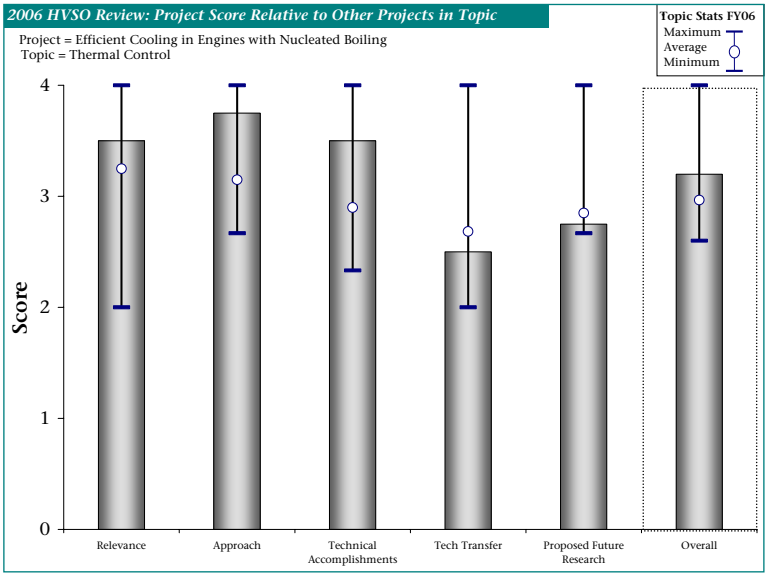
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 5 reviewers)

- Examine pumps is primary addition.
- Baseline testing of erosion tests with 3003 Al should be compared with data from industrial erosion test rigs at radiator manufacturers.
- Suggest waiting for more understanding of the basic phenomena to be developed.

Thermal Control

Efficient Cooling in Engines with Nucleated Boiling: Dave France, Argonne National Laboratory

Brief Summary of Project



This project team is investigating the potential of two-phase (liquid and vapor) flow in engine cooling applications as a means to increase heat transfer in heavy vehicle radiator systems. Increased heat transfer can potentially lead to smaller radiators for reduced vehicle frontal area, leading to reduced aerodynamic drag and improved fuel economy.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 4 reviewers)

This project was generally judged to be quite relevant to the DOE objectives. Improvements in cooling efficiency are a high priority in attaining improved efficiency engines and vehicles, according to one reviewer. Similarly, reduced cooling system sizes would be very beneficial to the need to better streamline and make aerodynamic improvements in heavy trucks. A reviewer observed that this program targets improved energy efficiency and reduced parasitic losses by allowing coolant to reach a two-phase state to increase heat removal capability without increasing coolant temperature. Finally, a reviewer said that this was a well presented research effort.

Question 2: Approach to performing the research and development (Written responses from 4 of 4 reviewers)

Several reviewers offered suggestions on the approach. The first reviewer said that the researchers are using fundamental, rigorous analytical and experimental approaches. This is essential to understanding how two-phase flow can be applied practically in engine design. The science is seemingly very sound, said the second reviewer, who also noted that one assumes that the heat capacity of the nanoparticles (versus that of the carrier fluid) is the reason for the enhanced performance. The third reviewer said that the project had an excellent technical approach to determine heat transfer and pressure drop characteristics of a boiling binary mixture of water/ethylene glycol. Some of the techniques to model this mixture are pioneering work in the field and have been cited by other experts in the field. Finally, a reviewer suggested that the use of horizontal and vertical test sections to simulate cooling to assist in the development of models seems OK but it's difficult to see how this can be connected to the complex surfaces and structures in real engines and radiators.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 4 reviewers)

The first reviewer said that in addition to the correlations developed for horizontal and vertical nucleate boiling under relevant conditions, the team has identified a useful regime for stable application of nucleate boiling heat transfer. Another said that very good progress has been made to date to meet program goals in horizontal flow boiling mode. There seems to be generally good progress towards the stated goals of the project, noted the third reviewer. The last reviewer said that again, the difference between what is "practical" and what is "science" leads to a rating of 3 out of 4. The flow in the passages of an engine "head" will not be developing flow in a cylindrical tube. The bridge to an industrial designer is relatively long. Guarantees that no vapor blocked hot spots will occur should be provided to such designers.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 4 reviewers)

The first reviewer said that citations of the team's work in the International Journal of Multiphase Flow are very

impressive, but the work was published in June 2002, and there is no further mention of tech transfer activity. This effort is seemingly too "new" to have gained industry buy-in, said a reviewer. It's not obvious that there is much need to collaborate with others at this stage of the research, noted another. Finally, a reviewer said that progress has been documented in conference papers, and that the team should look to meet with engine manufacturers to discuss control issues required to implement this concept in actual engine cooling systems.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 4 reviewers)

A reviewer said that there should be at least some work that moves the discoveries toward practical application. Another noted that the future work continues the science, and is good for Argonne. A reviewer thought that the plan to conduct studies in different orientations and with different potential fluids is a good approach. Finally, a reviewer said that the plans for future work don't seem to be very aggressive, but the work identified should be useful and achievable.

Specific Strengths and Weaknesses (Written responses from 3 of 4 reviewers)

- Specific Strengths
  - Fundamental and rigorous in both analytical and experimental efforts.
  - Experimental and modeling techniques for two-phase heat transfer coefficients and pressure drop.
  - A pretty good plan has been organized for this work.
- Specific Weaknesses
  - Technology transfer seems to be lagging.
  - Lack of collaboration with engine manufacturers.
  - May be difficult to translate to real components when the time comes.

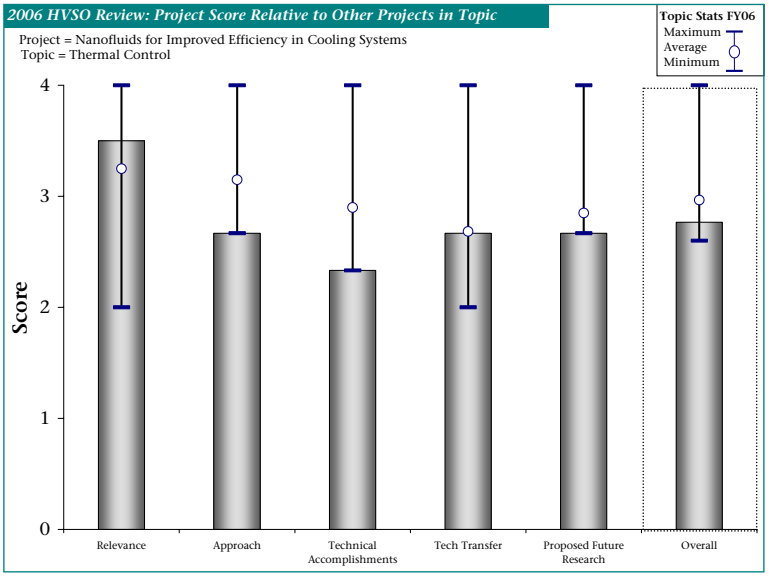
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 4 reviewers)

- No changes or recommendations at this time.
- Perhaps the team can engage an engine developer in an effort that attempts to address a cooling design issue in a real engine.
- Consider extension of two-phase coolant system to condensation of coolant in radiator to potentially reduce radiator size.

Thermal Control

Nanofluids for Improved Efficiency in Cooling Systems: Steve Choi, Argonne National Laboratory

Brief Summary of Project



Nanofluids are a new class of heat transfer fluids engineered by dispersing very small (nanometer-scale) particles in traditional fluids. This team is working to develop these fluids with ultra-high thermal conductivity, and to test their properties as well as determine the mechanisms by which these fluids achieve these high heat transfer rates.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 6 reviewers)

First, a reviewer said that the project was directly focused on energy efficiency. Improved heat transfer/heat rejection is an extremely desirable goal that would be important to the 21st Century Truck Partnership, said a reviewer. Another noted that cooling system advances that lead to reduction in radiator size can lead to huge energy savings, and use of nanofluids is one possible means by which radiators can be significantly reduced in size. In one reviewer's opinion, the general idea that fluids with better heat capacity would serve project goals well is good: so is the idea of checking out fluids with nanoparticles. Use of advanced nanofluids can benefit energy efficiency and reduced parasitic losses by improving thermal transport properties of coolant, said a reviewer. This was obviously a difficult presentation to make, in one reviewer's estimation, based on the principal investigator's discussion of unsuccessful CRADA negotiations for full vehicle cooling tests. Also, for a 1999 to 2009 project, 70% of the total effort is not behind them, this reviewer noted.

Question 2: Approach to performing the research and development (Written responses from 5 of 6 reviewers)

Thermophysical property and heat transfer/pressure drop characterization is essential for evaluation of these fluids, noted one reviewer. Another said that the approach wasn't clear from the slides. It isn't clear to this reviewer that basic scientific knowledge has been sufficiently obtained: relationship to fluid dynamics, etc. Approach will understand turbulent, laminar, etc. This reviewer was not sure it is time to move to development if it means abandoning research understanding. Another reviewer was unclear how nanoparticles were chosen, and noted that fluids with two volume percent gold are very impractical, and fluids with alumina are probably also impractical. The Einstein equation most probably does not work for nanparticulate fluids unless the total active diameter is used, in this reviewer's opinion. A reviewer said that the apparent "facts" regarding this effort do not argue for a score higher than 2 out of 4, and the actual presentation did not add to the confidence for this reviewer that this project was on-track.

The final reviewer said that their numeric rating was something of a guess: incomplete would probably be the more accurate rating. The presentation by Dr. Choi was "remarkably uninformative," according to this reviewer. This reviewer assessed the presentation as "18 minutes of largely useless generalities followed by less than 10 minutes of moderately useful information, which were followed by too little time for questions." For example, not a single heat transfer result was presented. From what this reviewer could glean, and then extrapolate by guessing, there is too much emphasis in this program on developing new nanofluids, and too little emphasis on examining the effects of nanofluids in radiator systems.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 6 reviewers)

One reviewer said that this was a very interesting technology and interesting advance. Another said that funding

of this project has slowed progress. Not much accomplished, said another reviewer, who noted that there was no discussion of why tube diameter might influence "viscosity" as it seems to do. Similarly, a reviewer observed that it seems that for a project that started in 1999 there has been relatively little progress and there doesn't seem to be much indication that the more significant technical barriers are on a path to be overcome. Another reviewer thought that it was possible that his numeric rating was too low, but based on what was presented to the group, the progress has not been rapid. Perhaps significant advances have been made in modeling, but they were not presented. Perhaps large bodies of data have been obtained and many observations made, but this reviewer was only judging what was presented. A final reviewer felt that these accomplishments must be acknowledged as "thin," especially when J. Hull emphasized that gold would not be used in an application. The Einstein viscosity is of doubtful applicability to nanoparticles.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 6 reviewers)

There have been good efforts to establish a CRADA with multiple industry partners, in one reviewer's mind. The contacts made to date and the apparent plans for deepening relationships seem to be adequate to another reviewer, who expected significant buy-in over the next year. Some industry interest seems demonstrated, noted another reviewer, who felt it was probably early in the project for expectations of more detailed interactions. A reviewer offered that the technology transfer was underdeveloped but seems to be able to grow quickly, and that funding uncertainty seems to have really hurt this project. A reviewer said that promises have been made but limited accomplishments were seen. Finally, a reviewer expressed the opinion that perhaps there are other areas of research involving nano-particles that would offer some insight into the behavior that is currently making progress difficult. This reviewer was impressed with the effort to characterize soot particles at the Argonne engine test cell facilities, and thought that maybe some of the techniques could be applied here to better understand how agglomeration occurs and how to avoid it.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 6 reviewers)

The first reviewer presumed that the model that stresses monosized particles is the basis for next year's work, since much focus is on a material of no industrial interest (gold). Yet not one detail was presented on that model, said this reviewer. It seemed to this commenter that the more fruitful path would be to work on a material that industry might actually use, in the best particle-size distribution the researchers now have, and then to demonstrate its effectiveness. The plans presented do not seem to allow the project to move toward commercialization rapidly enough, in this first reviewer's opinion. A second reviewer said that the team needs to deepen its theoretical approach and to bring in other fields: understanding of nonlinear viscosity: (shear thickening, etc.); filled polymer theory birth: gold, percolation, etc. A reviewer characterized the future research as seemingly a continuation of a limited scope. The future plans sounded good to one reviewer, but some science should go into design of experiments, selection of particles, etc. A reviewer said that the focus on heat transfer characteristics is a good next step. Finally, there needs to be more focus on the technical barriers to producing larger quantities of nanoparticle fluids that resolves the current difficulties before much progress can be made on the total approach with this concept.

Specific Strengths and Weaknesses (Written responses from 5 of 6 reviewers)

- Specific Strengths
  - A really big experimental breakthrough; wonderful experimental [procedures].
  - The sum total of evidence indicates nanofluids increase thermal conductivity remarkably and the ANL team has much expertise and experience in working with these fluids.
  - A very interesting concept has been discovered and developed that promises to offer substantial benefits once the appropriate technical barriers have been resolved.
  - Strong foundation.
  - Production methods for nanofluids. Strong research team.
  - General idea is probably good, certainly worth checking out.
- Specific Weaknesses
  - The biggest weakness was poor presentation of the research. Others include (apparently) insufficient

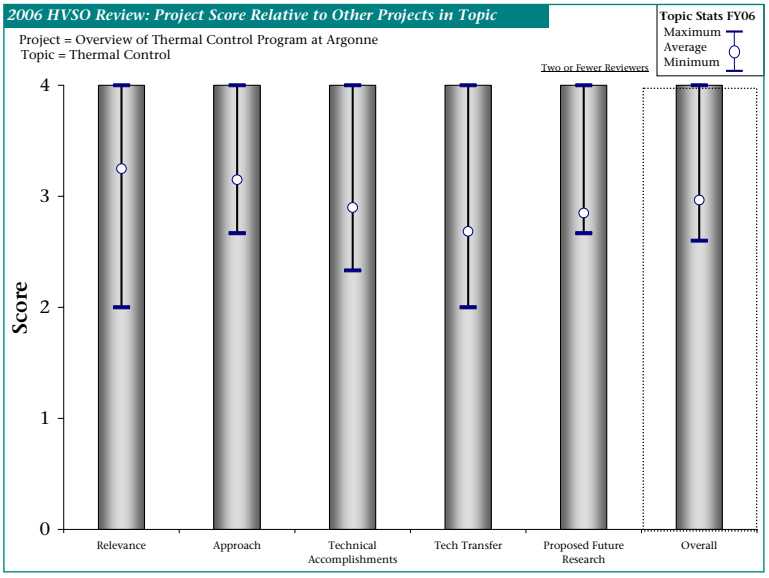
coordination between modeling and experiment, collection of too few useful data, and lack of focus on industrially useful fluid systems.
  - Fundamental mechanisms are known. This limits imagining applications and routes to make further large improvements. One volume percent versus particle collisions: what is importance of Brownian motion?
  - Lacks understanding of nanoparticulate behavior, surface/volume effects, and rational selection of particulates.
  - Lack of funding. Difficulty in obtaining large quantities of fluid for experimentation.
  - Much more focus has to be put on understanding how to generate and maintain nanoparticles in a fluid medium.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 6 reviewers)

- Best guess: focus on a single fluid system in an environment that matches that within a radiator, or better yet real radiator systems. Shift the new fluids work to a different funding source (perhaps BES, as was mentioned in the talk). Integrate modeling work into the experiments to as great an extent as possible.
- Study rubber/filler network formation: is this related? Can percolation theory explain the results? Does this work in solid systems? Does it need to be a fluid?
- Address understanding of nanoparticulate behavior, surface/volume effects, and rational selection of particulates.
- Consider a miniaturized cooling system to measure performance benefits. These liquid cooling systems exist for cooling high end desktop computers and may be a way to evaluate heat transfer / thermal conductivity performance benefits of nanofluids with a small quantity of fluid.
- It would be helpful to look for help in other nanoparticle research areas to see if something can be done with a modified approach.

Thermal Control

Overview of Thermal Control Program at Argonne: John Hull, Argonne National Laboratory



Brief Summary of Project

This presentation was an overview discussion of the thermal control research being conducted at Argonne, and was intended to provide a programmatic overview of the research done by Steve Choi, Dave France, and Dileep Singh. The goal of the thermal control program is to improve the efficiency of vehicle heat rejection systems in order to reduce parasitic energy losses through the system itself (fans, pumps, etc.) and to reduce the size of the radiators, thus reducing vehicle frontal area and resulting aerodynamic drag.

Question 1: Relevance to overall DOE Objectives (Written responses from 1 of 1 reviewers)

The commenting reviewer felt it was obvious that reduction of aerodynamic drag can provide the biggest benefits to fuel consumption. It was also obvious to this reviewer that simple approaches that can lead to near-term successes are critical to maintaining interest in and support for this program. The projects described in this presentation can provide such successes. This comment also covers other work to which Dr. Hull is contributing: nucleate boiling and nanofluids.

Question 2: Approach to performing the research and development (Written responses from 1 of 1 reviewers)

The disparate efforts each contribute significantly, and each should be economically viable, commented this reviewer. As is common in the 21CTP program, the balance between modeling and experimentation is nearly ideal.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 1 of 1 reviewers)

For such a recent start, the accomplishments have been impressive, in this reviewer's opinion. The modeling results appear to be quite promising.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 1 of 1 reviewers)

The support from Cummins is truly outstanding and the match with Caterpillar's goals and approaches is as well.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 1 reviewers)

This reviewer felt the future research plan was ideally focused on what industry needs and wants.

Specific Strengths and Weaknesses (Written responses from 1 of 1 reviewers)

- Specific Strengths
  - Clear and clearly important goals, strong industrial support and interaction, talented teams with good collaborations in place.
- Specific Weaknesses
  - None that I could identify.

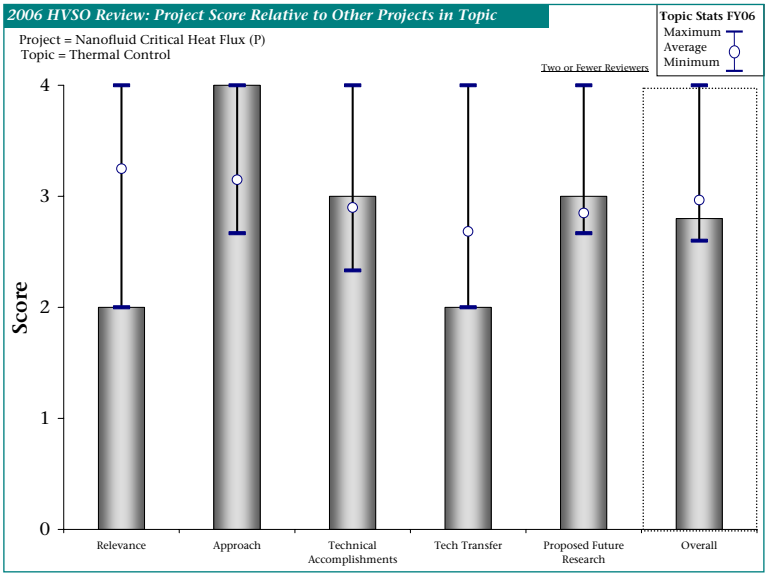
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 1 reviewers)

- Recommend that they stay the course.

Thermal Control

Nanofluid Critical Heat Flux (Poster): Steve Choi, Argonne National Laboratory

Brief Summary of Project



This activity had several major objectives: determine the feasibility of nanofluid coolants in heavy vehicle engine cooling; test typical fluids (water, ethylene glycol, and mixtures); quantify single-phase heat transfer enhancement and pressure drop of nanofluids; and consider two-phase flows and determine characteristics of nanofluid boiling.

Question 1: Relevance to overall DOE Objectives (Written responses from 1 of 1 reviewers)

The sole reviewer for this project offered that single-phase aspects of the program should lead to the continued progress on improved energy efficiency and reduced parasitic losses. Two-phase work may lead to progress in overcoming these barriers, but will require acceptance of nucleate boiling of conventional fluids first which may take some effort.

Question 2: Approach to performing the research and development (Written responses from 1 of 1 reviewers)

One reviewer commented that there was an excellent experimental approach to determining relevant heat transfer parameters of nanofluids.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 1 of 1 reviewers)

Good initial progress towards experimental setup validation and calibration for the small amount of funding provided, noted the only reviewer.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 1 of 1 reviewers)

The only reviewer would like to see more interaction with industry on test progress as well as translation of potential findings to industry.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 1 reviewers)

The reviewer felt there was a good plan for completion of work.

Specific Strengths and Weaknesses (Written responses from 1 of 1 reviewers)

- Specific Strengths
  - Excellent test plan and setup.
- Specific Weaknesses
  - Lack of industrial participation. Two-phase work very exploratory in nature; need to quantify experimentally benefits of single-phase nanofluids first.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 1 reviewers)

- Consider combining nanofluid activities into one project to pool resource dollars. Focus on single-phase heat transfer activities to identify best short term benefits of nanofluids.

HEAVY VEHICLE SYSTEMS OPTIMIZATION MERIT REVIEW AND PEER EVALUATION

Evaluation Form **April 2006**

TOPIC: _____

PRESENTER: _____

REVIEWER NAME: _____

Using the following criteria, please rate the **work** presented in the context of the program objectives. Please provide **specific** comments to support your evaluation.

1. Relevance to overall DOE objectives (degree to which this project supports the goals and objectives of the 21 CT Program and DOE Multi-Year RD&D Plans).

Numeric rating (circle one below)
4 = Outstanding, the project is sharply focused on one or more key technical barriers related to systems optimization.
3 = Good, most aspects of the project will contribute to significant progress in overcoming these barriers.
2 = Fair, some aspects of the project may lead to progress in overcoming some barriers.
1 = Poor, the project is very unlikely to make significant contributions to overcoming the barriers.

Specific comments

2. Approach to performing the research and development (degree to which technical barriers are addressed: quality of project design, technical feasibility, and integration of project with other research).

Numeric rating (circle one below)
4 = Outstanding, it is difficult for the approach to be improved significantly.
3 = Good, the approach is generally well thought out and effective, but could be improved in a few areas.
2 = Fair, the approach has significant weaknesses.
1 = Poor, the approach is not responsive to the project objectives.

Specific comments

3. Technical Accomplishments and Progress toward project and DOE goals (degree to which progress is gauged against performance measures, and degree to which the activities improve the state-of-the-art in performance relative to DOE program goals).

Numeric rating (circle one below)
4 = Outstanding, the project has made excellent progress toward overcoming one or more key DOE program technical barriers; progress to date suggests that the barrier(s) will be overcome.
3 = Good, the project has shown significant progress toward overcoming barriers.
2 = Fair, the project has shown a modest amount of progress in overcoming barriers, and the overall rate of progress has been slow.
1 = Poor, the project has demonstrated little or no progress toward overcoming the barriers.

Specific comments

4. Technology Transfer/Collaborations with industry, universities, and other laboratories (how well do the project team members relate with other institutions and projects).

Numeric rating (circle one below)
4 = Outstanding, close coordination with other institutions is in place; industrial partners are full participants.
3 = Good, some coordination exists; full coordination could be accomplished fairly quickly.
2 = Fair, some coordination exists; full coordination would take significant time and effort to initiate.
1 = Poor, most or all of the work is done at the Lab with little outside interaction.

Specific comments

5. Approach to and Relevance of Proposed Future Research (how well will the future research plan achieve the goals set forth for the project and for the DOE programs in general).

Numeric rating (circle one below)
4 = Outstanding, future work plan builds on past progress and is sharply focused on one or more key DOE program technical barriers.
3 = Good, future work plan builds on past progress and generally addresses removing or diminishing barriers in a reasonable timeframe.
2 = Fair, future work plan may lead to improvements, but should be better focused on removing or diminishing key barriers within a reasonable time period.
1 = Poor, future work plan has little relevance or benefit toward eliminating barriers.

Specific comments

6. Specific Strengths of This Research

7. Specific Weaknesses of This Research

8. Specific Recommendations or Additions/Deletions to Work Scope

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Acronym	Definition
21CTP	21st Century Truck Partnership
ANL	Argonne National Laboratory
APS	Advanced Photon Source at Argonne
APU	Auxiliary power unit
BES	DOE Office of Basic Energy Sciences
CFD	Computational Fluid Dynamics
CRADA	Cooperative Research & Development Agreement
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EGR	Exhaust gas recirculation
FMCSA	Federal Motor Carrier Safety Administration
FTC	Federal Trade Commission
FY	Fiscal Year
GTS	Ground Transportation System (truck aerodynamic modeling configuration)
KULI	Software tool for vehicle heat management optimization
LLNL	Lawrence Livermore National Laboratory
MRF	Multiple reference frames
NASA	National Aeronautics and Space Administration
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute of Standards and Technology
NOx	Oxides of nitrogen
OEM	Original Equipment Manufacturer
PIV	Particle Image Velocimetry
R&D	Research and development
SAE	Society of Automotive Engineers
TMA	Truck Manufacturers Association
TTI	Texas Transportation Institute
USC	University of Southern California
ZDDP	Zinc dialkyl dithiophosphate (lubricating oil additive)

A Strong Energy Portfolio for a Strong America
Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as vital new "energy carriers."

The Opportunities
Biomass Program
Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program
Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program
A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program
Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program
Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program
Tapping the Earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program
Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program
Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program
Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and businesses

Wind & Hydropower Technologies Program
Harnessing America's abundant natural resources for clean power generation

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