

# FY13 RWDC Surface Challenge



## Background

Heavy-duty trucks are the fastest-growing contributors to greenhouse gas emissions within the transportation sector and account for a significant portion of domestic oil use:

- Transportation accounts for about 72 % of our total petroleum consumption.
- Heavy-duty vehicles account for 17 % of transportation oil use – and 12 % of all US oil consumption.
- Nearly 6 % of all U.S. greenhouse gas emissions and 20 % of greenhouse gas emissions from the transportation sector in 2007 were produced by heavy-duty vehicles.

In recent years, new national standards have been introduced to improve energy and national security, benefit consumers and businesses, reduce harmful air pollution, and lower costs for transporting goods while spurring growth and innovation in the clean energy technology sector.

## Challenge

The challenge is to design and evaluate efficiency improvements for a baseline heavy-duty combination truck (tractor trailer) while working within several real-world constraints:

- meeting a minimum fuel economy standard (6 mpg)
- designing and selecting fuel-saving technologies that provide the best benefit for the lowest cost
- complying with existing Federal safety regulations

Each team will design aerodynamic improvements for a baseline CAD model of the tractor trailer, and then evaluate the effect of those improvements using Computational Fluid Dynamics. Aerodynamic improvements are combined with the team's other choices for enhancements to tires, engine, and vehicle structure. These choices are incorporated into a comprehensive efficiency simulator (FASTSim) to determine the overall benefit. The maximum aerodynamic benefit that the team is able to achieve over the baseline model in CFD analysis (% drag reduction) will be the maximum drag reduction which is available to that team when selecting inputs into the simulator. To be successful, teams will design aerodynamic modifications and select enhancements to the tires, engine and structure so that the fuel efficiency standard is met and safety is maintained at a minimum cost to the vehicle operator.

## Objective Function

The objective function to be minimized in pursuit of winning the above challenge can be written:

$$Of = C - F$$

Where  $C$  is the up-front cost of the improvements made to the vehicle and  $F$  is the dollar value of the fuel savings over 3.5 years of operation for one vehicle. While the objective function is simple in form to

highlight the objectives of the challenge, the derivation of the constituent parts is non-trivial, and will constitute the majority of your efforts on this challenge.

## Assumptions and Constraints

The first focus is on exploring improvements to vehicle performance. The provided baseline vehicle (tractor plus trailer) FASTSim model weighs 25,000 lbs empty and when carrying 30,000 lbs of cargo achieves roughly 4.9 mpg on the simulated drive cycle. The selected drive profile is the full Heavy Heavy-Duty Diesel Truck (HHDDT) cycle, which includes four modes of operation: idle, creep (in slow-moving traffic or around a loading dock), transient (in town stop-and-go), and high speed. *This baseline fuel economy must be improved to at least 6.0 mpg* through implementing design changes to aerodynamic drag, the weight of the empty vehicle, tire rolling resistance, and/or engine efficiency. Note that your own aerodynamic modeling will determine the maximum aerodynamic improvement permitted for use in your FASTSim model, though you are permitted to use a lower-than-maximum value if that improves your objective function.

The next focus is to minimize the net cost for the vehicle design changes which are required to achieve the 6.0 mpg minimum constraint. The net cost (the Objective Function above) is assessed using a simple 3.5-year payback calculation. Net cost equals the incremental cost to implement the efficiency improvement technologies up front, minus the fuel savings achieved by these technologies over 3.5 years relative to the baseline vehicle (assuming 15,000 miles driven per year, and \$4.50/gal diesel fuel cost). To benefit the operator, it is necessary-desired to achieve a “negative” net cost (to save more than you spend). The following tables define the maximum parameter changes that teams are permitted to implement and the associated incremental cost from each efficiency improvement technology.

**Table 1. Maximum Parameter Changes Allowed**

Parameter	Maximum Reduction	Incremental Cost
<b>Aerodynamic Drag</b>	Lesser of: <ul style="list-style-type: none"> <li>• 30%</li> <li>• maximum achieved in CFD</li> </ul>	\$150 per % drag reduction
<b>Empty Vehicle Weight</b>	5,000 lbs	\$2 per lb empty vehicle weight reduction
<b>Rolling Resistance</b>	20%	\$35 per % rolling resistance reduction

**Table 2. Available Engines**

Available Engines	Incremental Cost
<b>Engine 1</b>	\$0 (Baseline)
<b>Engine 2</b>	\$3,500
<b>Engine 3</b>	\$7,000

## Resources

- RWDC Surface Challenge Detailed Background document
- Standard FASTSim download link (a challenge-customized version will be provided to students separately): <http://www.nrel.gov/vehiclesandfuels/vsa/fastsim.html>
- U.S. Environmental Protection Agency and U.S. Department of Transportation, “Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule,” September 2011.
  - Volume 76 of the Federal Register page 57106 at <https://www.federalregister.gov/articles/2011/09/15/2011-20740/greenhouse-gas-emissions-standards-and-fuel-efficiency-standards-for-medium--and-heavy-duty-engines>
- Hucho, Wolf-Heinrich, Editor, “Aerodynamics of Road Vehicles.” Society of Automotive Engineers, Inc., Warrendale, PA, 1998.
- U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 21<sup>st</sup> Century Truck Partnership, “Roadmap and Technical White Papers,” 21CTP-0003, December 2006.
  - [http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/21ctp\\_roadmap\\_2007.pdf](http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/21ctp_roadmap_2007.pdf)
- Mentors from government, industry, and academia.
- Title 49 of the Code of Federal Regulations Part 393
  - <http://www.fmcsa.dot.gov/rules-regulations/administration/fmcsr/FmcsrGuideDetails.aspx?menukey=393>
- Title 23 of the Code of Federal Regulations section 658.16(b)(4)  
<http://ops.fhwa.dot.gov/freight/sw/aerodevice23cfr65816.htm>

## Software Tools

- Creo Elements/Pro, Mathcad, and Windchill provided by PTC.
- FloEFD.Pro aerodynamic analysis software provided by Mentor Graphics.
- Future Automotive Systems Technology Simulator (FASTSim) provided by the US. Department of Energy’s (DOE) National Renewable Energy Laboratory (NREL)

## Scoring

- Technical scoring will be based on deliverables to be incorporated in the Design Notebook.
- Design Notebooks should be structured to follow the Scoring Rubric.
- Judges will be looking for ability to express comprehension, especially the linkage between design decisions and outcomes.

## Merit Awards

~~Special RWDC Merit Awards will be given at the RWDC National Challenge Championship in Washington DC. Merit awards will be granted at judge's discretion to teams that do not place in the top three, but are top performers overall. Only one merit award will be granted per team.~~—Awards will be based on team submissions.

- Innovation
- Design Viability
- Team Work and Collaboration
- Effective Use of Mentors
- Impact on STEM
- Against All Odds
- Best Business Case
- Best First Year Team

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