



# VOLVO TRUCKS NORTH AMERICA



# THE VOICE OF EXPERIENCE

**Raja Sengupta**

**Lead Engineer—Aerodynamics, Volvo Trucks North America**

In today's connected, global economy with its streamlined supply chain, goods are transported all over the world. As they make their way to a store near us or, increasingly, to our doorsteps, they were invariably transported there by trucks, at least for some part of that journey. In an age of online shopping—especially in the wake of the recent COVID-19 lockdowns—trucking is critical to our daily lives.

However, the transportation of goods and people today are mostly powered by fossil fuels, which emit greenhouse gases (GHG) when burned. In the US, the transportation sector accounted for 28% of the overall GHG emissions in 2018—and 23% of that sector emission came from medium and heavy-duty trucks [1]. This makes the trucking industry a major player in the effort to minimize tailpipe emissions of GHG.

At Volvo Trucks, care for the environment is one of our core values. We believe in sustainable transport solutions. Although electric trucks are here, we know that their widespread adoption may take some time. Therefore, in addition to our investment in electric and hydrogen-powered trucks, we are also focused on reducing the tailpipe GHG emissions of our diesel-powered trucks, to carry society through this transition period.

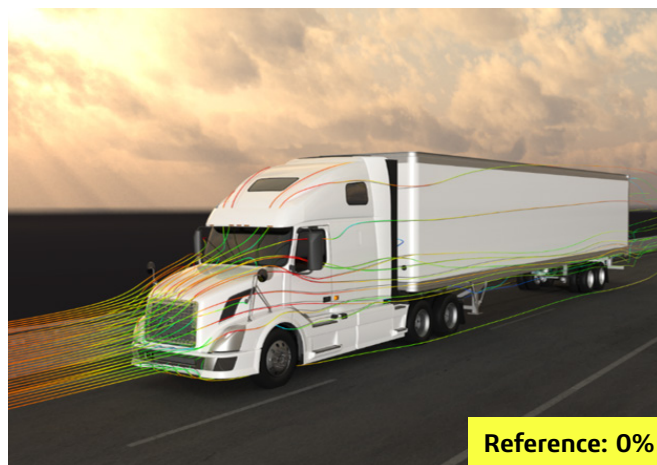
For the past decade, we have done some of that work as part of the US Department of Energy's "Supertruck" program to improve the freight efficiency—measured in ton-miles per gallon (or ton-mpg)—of diesel-powered, heavy-duty Class 8 tractors. These trucks, which account for only 4% of the vehicles on US roads, use about 20% of US transportation fuel [2].

In the original Supertruck program (ST1), participants were challenged to improve the freight efficiency by 50% over a 2009 baseline. Among all competitors, the "average" 2009 baseline offered 90 ton-mpg [3]. A 50% improvement, therefore, would have achieved a freight efficiency of 135 ton-mpg.

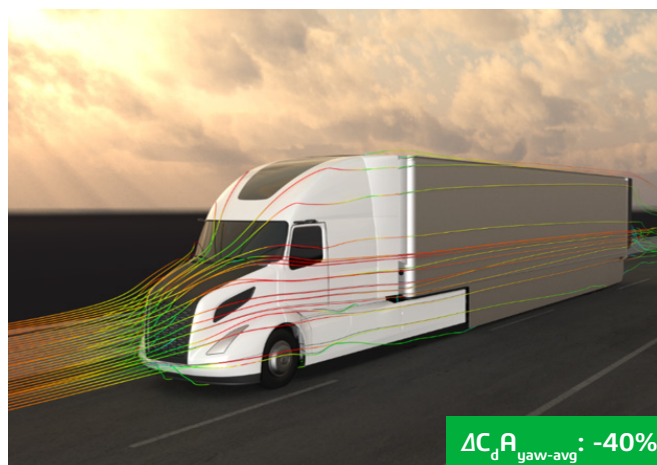
Determined to challenge ourselves, we chose as our baseline the Volvo VNL 670—our most efficient highway tractor in 2009, offering 100 ton-mpg (at 65,000lbs Gross Vehicle Weight). Ultimately, Volvo's ST1 delivered a freight efficiency of approximately 188 ton-mpg—an 88% improvement over our baseline.

There were three main contributors to this: reducing the weight of the tractor and the trailer, improving the efficiency of the powertrain, and drastically reducing the aerodynamic drag, for which my team was responsible.

To improve on the aerodynamic design of our baseline required extensive experimentation. Fortunately, Volvo Trucks is an advanced user of virtual experience twin technology (also known as "digital twin" technology). This powerful combination of virtual 3D design and multi-physics CFD (Computational Fluid Dynamics) simulation allows us to experiment in the "Digital Wind Tunnel" with real-life accuracy, testing thousands



MY2009 Baseline



Supertruck 1, ~40% drag reduction was critical to achieving the Freight Efficiency target.

of variations in a fraction of the time and cost that would be required for testing with physical prototypes.

Unlike physical wind tunnels, where design development is mostly sequential, i.e., a series of trial and errors to incrementally improve a design, the virtual process also allows exploration of a much larger design space using DOE (Design of Experiment) optimization tools coupled with a "Digital Clay" process that offers parametric modification or morphing of design surfaces.

We made extensive use of both—applying the latter on large surfaces, such as the trailer boat tail panels, to find the optimum length, position, and angle of the panels. While the sequential approach was used mostly to iterate on the tractor design—meeting the engine cooling need while minimizing its aerodynamic impact (also known as cooling drag), shaping the front end around the cooling package and in general, minimizing obstructions to the airflow as it makes its way around the tractor-trailer system.

A unique advantage of the Supertruck project is our ownership of the complete system—from the bumper to the boat tail—which, in turn, offers us unique synergies. For example, by





MY2009 Baseline



Volvo ST2 achieved ~50% drag reduction over baseline (~20% over ST1).



Volvo Supertruck 2. SIMULIA PowerFLOW is a powerful tool to improve aerodynamics at any stage of design development.

By integrating the chassis fairings to the trailer skirt, we were able to completely cut out pathways for airflow to enter under the tractor-trailer from the sides. This allowed us to design an effective air dam under the front bumper which minimized air getting under the vehicle and creating additional drag as it encounters low-hanging chassis components. This would not be as effective without an aerodynamic trailer as the suction created by the air dam under the vehicle would draw in air from the sides and increase the drag on the trailer bogie. It's a little-known fact that almost half of the aerodynamic drag on a modern tractor-trailer system is generated from the trailer base (door) and the trailer bogie. This is why trailer aero devices (skirts and boat tails) are so effective in reducing fuel consumption for large fleets.

Unlike physical testing, our virtual experience twin process offers detailed visual insight about the airflow around the vehicle. This is critical as it drives our iterative design process—every design change is based on learnings from the previous iteration, thereby continuously improving the aerodynamics until we reach saturation or diminishing returns. After hundreds of tweaks and dozens of iterations, we were able to reduce the

overall aerodynamic drag of ST1 by 40%, yielding a 20% direct improvement in fuel economy. But there were indirect benefits as well.

At a cruise speed of 65mph, almost half of the road load on a tractor-trailer comes from the air resistance or aerodynamic drag. Therefore, by drastically reducing the drag, we were able to downsize our engine—from a 13L 485HP in the baseline to a 11L 425HP in ST1. This reduced the weight of the tractor (thereby increasing payload and therefore, freight efficiency) and lowered the engine cooling demand from what was originally anticipated, which meant we could use a smaller cooling package. This resulted in a narrower hood, smaller grille opening and a much lower cooling drag.

On the heels of the success of ST1, the DOE initiated the Supertruck II (ST2) program in 2016 and doubled the challenge—to achieve 100% improvement over the same 2009 baseline. The project is still on-going as we enter the final, build phase. However, the tractor-trailer design was frozen a while back, a culmination of a similar process as ST1 powered by the same virtual experience twin technology. This time, we reduced the overall drag by 50% over our 2009 baseline—almost 20% over ST1.

Coupled with the improvements achieved by our powertrain colleagues, Volvo's ST2 is expected to deliver a 120% improvement over our baseline, achieving 220 ton-mpg. The validation of our virtual experience twin results with the physical prototype, currently under construction, should happen in the coming months.

As a demonstrator, Supertruck is similar to a concept car; while many of the improvements already are, or soon will be, incorporated into our commercial offerings, others need more work to bring down their cost. And Supertruck II isn't the end of the journey: the recently announced Supertruck III program will focus on battery-electric and fuel-cell-powered vehicles—the designs that will move the trucking industry from a transitional period of lower tailpipe GHG emissions to one with zero tailpipe emissions.

[1] "Fast Facts on Transportation Greenhouse Gas Emissions." EPA, Environmental Protection Agency, 8 June 2021, [www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions](http://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions).

[2] Lobner, Peter. "SuperTrucks—Revolutionizing the Heavy Tractor-Trailer Freight Industry with Science." The Lyncean Group of San Diego, 3 Apr. 2020, <https://lynceans.org/tag/doe-supertruck/>.

[3] Delgado, Oscar and Nic Lutsey. "THE U.S. SUPERTRUCK PROGRAM" [https://theicct.org/sites/default/files/publications/ICCT\\_SuperTruck-program\\_20140610.pdf](https://theicct.org/sites/default/files/publications/ICCT_SuperTruck-program_20140610.pdf).

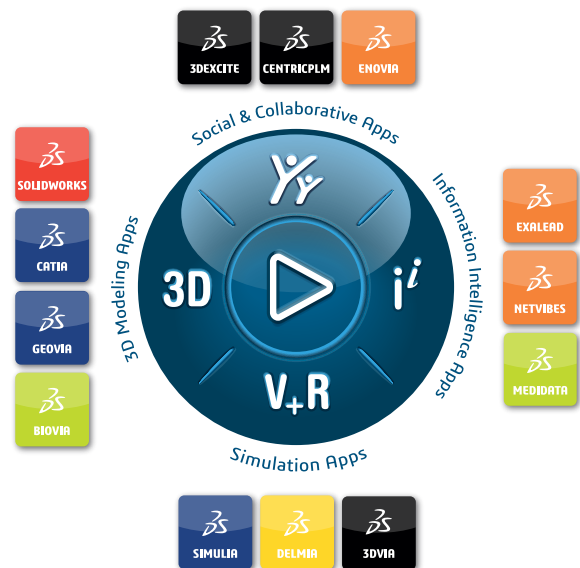
## PROFILE

Raja Sengupta is Lead Engineer for Aerodynamics at Volvo Trucks North America, responsible for aerodynamic certification for CO2 of the company's product portfolio. He also led Volvo Trucks' aerodynamics development team for the US Department of Energy's Supertruck I program, and currently leads Volvo Trucks' aerodynamics team for the Supertruck II program. He has a doctoral degree in aerospace engineering from the University of Cincinnati, and previously worked for NASA Langley, the motorsports industry, and for a simulation software developer, where he specialized in simulation for engine cooling and full-truck simulation.

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