Designing a SMART TRUCK with the power of Jaguar

One of these days as you’re traveling down the interstate, don’t be surprised if you see an 18-wheeler that looks more like a low-flying airplane than the familiar big rig. A perfect storm of factors is providing the impetus to revolutionize truck design, including high fuel costs, heightened environmental awareness, and mandates from state and federal agencies to boost fuel efficiency and reduce carbon emissions. Today’s trucks average only 6 mpg or less and add a whopping 423 million pounds of CO2 to the atmosphere every year. However, new California Air Resources Board regulations mandate a minimum mileage improvement of 5 percent for long-haul trucks operating within the state’s borders.

For truck owners, CARB is a headache. For SmartTruck Systems in Greenville, South Carolina, the new rules present a golden opportunity. Says Mike Henderson, CEO of SmartTruck, “CARB and the other regulatory rules impacting the trucking industry are opening up an entirely new market for us.” Before founding SmartTruck Systems, Henderson was a 30-year veteran of the Boeing Company. He and his team of engineers are specialists in the design of aerodynamically advanced aircraft as well as racing and motorsports vehicles. That experience includes the use of advanced modeling and simulation techniques made possible by computational fluid dynamics (CFD) software running on high-performance computers—a set of skills that they now apply to the problem of making Class 8 trucks more fuel-efficient and less polluting.
Retrofitting what’s already on the road

SmartTruck took a both short- and long-term approach to complying with present and future mandates. First, given the impending CARB regulations, completely redesigning the long-haul trucks from the tires up was not an option. Instead, they needed an economical, efficient solution that could be applied to trucks already on the road. Then, they could turn their attention to a “clean sheet” design for the truck of the future. SmartTruck’s answer to its immediate need was to launch the Smart Truck program.

“Our first goal is to design add-on parts for existing trucks to make them more aerodynamic,” Henderson says. “By reducing drag we boost fuel efficiency and cut the amount of carbon that’s being dumped into the environment. Once we have the existing fleets retrofitted, we can turn to creating a brand new, highly aerodynamic vehicle with optimum fuel efficiency.”

A Class 8 truck consists of two parts—the tractor, a motorized vehicle that is used to tow a trailer, a large container unit without an engine, front wheels, or front axle. Combined, the two units are called an 18-wheeler, referring to the truck’s total number of tires.

Initially, the SmartTruck team used a high-performance computing cluster to model drag-reducing parts for the trailer by simulating the action of complex airflows over and around a typical unit. The team used a conventional HPC cluster with a limited number of computing cores—and they were not happy with the results. “On the conventional cluster we had to simplify the problem,” Henderson explains. “We couldn’t handle the really complex models—the solutions lacked accuracy. We could explore possibilities, but we couldn’t run the detailed simulations needed to verify that the designs were meeting our fuel-efficiency goals.”

SmartTruck Systems was, as they say in computer industry jargon, computebound. Its engineers needed orders of magnitude additional computing capability, both to run highly detailed, accurate models of the trailer retrofit components and to get the results in time to meet the looming CARB deadlines.

Hunting a Jaguar

At the recommendation of some aerospace colleagues, SmartTruck approached the Oak Ridge Leadership Computing Facility at ORNL. Through the laboratory’s Industrial HPC Partnership Program, SmartTruck applied for and received access to the extraordinary computational capabilities of the Jaguar high-performance computer. Access to Jaguar allowed SmartTruck Systems to design the UnderTray System, a unique group of aerodynamic add-on parts that minimizes drag associated with the trailer’s underside components. The UnderTray System compresses and accelerates incoming airflow as well as injecting high-energy incoming air and attached airflow from the top of the trailer down into the trailer’s wake.

On the smaller HPC clusters that SmartTruck was using before moving to Jaguar, running a model of a typical UnderTray component might take 4 days and use every resource the cluster had to offer. Jaguar allows the SmartTruck engineers to break the truck into hundreds of pieces in order to calculate drag with a high degree of accuracy. Says John Anastas, SmartTruck project engineer, “Breaking the model down into that many pieces and resolving the flow on each one is something you can’t do with a small cluster—it would take weeks to get a solution. But with Jaguar we can do whatever we want in terms of complexity and still get reasonable results that allow us to turn the design around in hours instead of days. All we leave out are the nuts and bolts—every other detail is represented in the computer.”

Impact at a glance

Jaguar is DOE’s flagship supercomputer. With almost a quarter of a million processing cores and a theoretical peak computational capability of 2.3 petaflops, the world’s largest Cray XT was more than able to provide SmartTruck Systems with all the computational power it needed. (A petaflop is a measure of a computer’s processing speed and refers to a thousand trillion [one quadrillion] floating point operations per second.) In addition, SmartTruck opted to run the FUN3D application, the National Aeronautics and Space Administration’s CFD software that is used widely in the aerospace industry.

Challenge

- Design retrofit parts for Class 8 long-haul trucks (18-wheeler) to improve fuel efficiency in time to meet looming California regulations

Solution

- Tap into the power of Jaguar, the Department of Energy’s flagship high-performance computer at ORNL, to run detailed simulations in record time

High-performance computing impact

- Run simulations based on the most complex tractor and trailer model ever devised instead of simplified models, and run them faster
- Dramatically shorten design turnaround from days to a few hours
- Eliminate the need for costly and time-consuming physical prototypes

Business benefits

- Significantly reduce time-to-market for new products from more than 3 years to 18 months
- Pass EPA tests with new parts on first attempt, an unprecedented result in this industry
- Increase revenue and market share opportunity
- Assume leadership position in an emerging industry with great potential
- Strengthen the manufacturers engaged in production

Design digitally, confirm physically

Access to Jaguar led SmartTruck to the holy grail that many manufacturers seek: the ability to substantially reduce or completely bypass the costly and time-consuming process of creating multiple physical prototypes in the design phase of new product development. Comments Henderson, “Developing these parts through physical experimentation is a real exercise in frustration, which is one reason it hasn’t been done. It’s extremely expensive, and you don’t learn with a CFD solution. So we develop our designs computationally, and then confirm them physically through testing to be sure we haven’t..."
Trailers equipped with SmartTruck Systems components can achieve seven to twelve percent better fuel mileage. (Images: SmartTruck Systems)

From calculation to compliance

“We were pleased to see how close our CFD simulations matched the physical test results,” says Henderson. “The process works—physical test results were within 1 percent of our CFD calculations, and we were able to pass Environmental Protection Agency fuel tests on the first try—something almost unheard of in our industry. Without Oak Ridge and Jaguar it would be impossible to be where we are today.”

The EPA SmartWays program has certified the UnderTray system components with a 6.8 percent fuel savings, designating them as CARB-compliant for use in California. This goal was reached with a minimum package; a full set of UnderTray components provides nearly a 12 percent savings. If all of the 1.3 million Class 8 trucks in the country were configured with just the minimum package of new components, the United States could annually save almost 1.5 billion gallons of diesel fuel; reduce CO₂ by 32.7 billion pounds (16.4 million tons); and save $4.42 billion in fuel costs.

Launching an industry

In the highly competitive industrial world, cool designs matter only if they generate hard cash. By bringing products to market faster, SmartTruck Systems will realize revenue earlier and move into a leadership position in a new industry. With this early-to-market advantage, the companies should capture even greater market share, increasing their revenue opportunity.

However, the positive economic impact extends beyond Smart-Truck. The parts for the Smart Truck retrofits are being manufactured in Georgia by Cellofoam, and the various metal hardware components, such as screws and brackets, are being manufactured by a variety of metal companies in South Carolina. In today’s stressed economic environment, the addition of any type of domestic manufacturing is beneficial to both the region and the country as a whole, providing economic stimulus at the local and national levels.

Next steps

Market receptivity has been positive and quick. Heavy Duty Trucking magazine, a leading industry publication, named the new UnderTray system one of the top 20 products of the year. The first production UnderTray products are being installed on fleets owned by Smart-Truck Systems customers Frito-Lay, Swift Transportation, and Conway Truckload, permitting the fleets to move products into and throughout California. The company has embarked on the next phase of its truck-retrofitting program with the design of a new aerodynamic trailer configuration and fuel-efficient modifications to existing tractors.

At the same time, SmartTruck is taking the first steps toward its long-term goal: the design of a highly aerodynamic truck from the ground up—an ambitious “clean sheet” project. In the not too distant future, this work will culminate in the creation of “Super Truck,” a futuristic vehicle with astonishing fuel efficiency that may bear little resemblance to the classic big rigs currently on the road.  
—John Kirkley

overlooked a problem. With the speed and power of Jaguar, we were able to create and evaluate the most complex model of a trailer to date and dramatically accelerate that design process.”

The approach worked. When it came to correlating the computer-generated simulations with physical tests in the field, the SmartTruck team scored an A+. The team’s test truck, loaded with prototype components and telemetry, was put through its paces on the world’s longest, smoothest concrete landing strip—the 18,000-foot runway at the Kennedy Space Center. These tests confirmed the accuracy of the CFD simulations and the operational efficiency of the new add-on component designs based on those simulations.