OLCF
Oak Ridge Leadership Computing Facility

Industrial HPC Case Study

Cray Jaguar XT5 supercomputer
Image courtesy ORNL

Impact at a Glance

Challenge

- Design retrofitable parts for Class 8 (18-wheeler) long haul trucks 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 Oak Ridge National Laboratory, 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 need for costly and time consuming physical prototypes

Business Benefits

- Pass EPA tests with new parts on first attempt, an unprecedented result in this industry
- Significantly reduce time-to-market for new products
- Increase revenue and market share opportunity
- Assume leadership position in an emerging industry with great potential

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 a Class 8 (18-wheeler) truck that looks more like a low-flying airplane than the familiar big rig.

There is a perfect storm of factors 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 six mpg or less and add a whopping 423 million pounds of CO_2 to the atmosphere every year. That is no longer acceptable.

Not surprisingly, California is leading the way in pioneering environmental initiatives that impact the trucking industry. The new California Air Resource Board (CARB) regulations mandate a minimum mileage improvement of 5% for long haul trucks operating within the state's borders.

For truck owners, CARB is a headache. For BMI Corporation, an engineering services firm based in Greenville SC, the new rules are a golden opportunity. Says Mike Henderson, CEO and founder of BMI, "CARB and the other regulatory rules impacting the trucking industry are opening up an entirely new market for us."

Before founding BMI, 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 CFD (computational fluid dynamics) software running on high performance computers (HPC) – a set of skills that they are now applying to the problem of making Class 8 trucks more fuel efficient and less polluting.

Retrofitting What's Already on the Road

BMI took a both a 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 and efficient solution that could be applied to trucks already on the road. Then they could turn their attention to a "clean sheet" design of the truck of the future. BMI'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 our attention 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 larger container unit without an engine, front wheels or a front axel. Combined, the two units are called an 18-wheeler, referring to the truck's total number of tires.

Initially, the BMI team used an HPC 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."

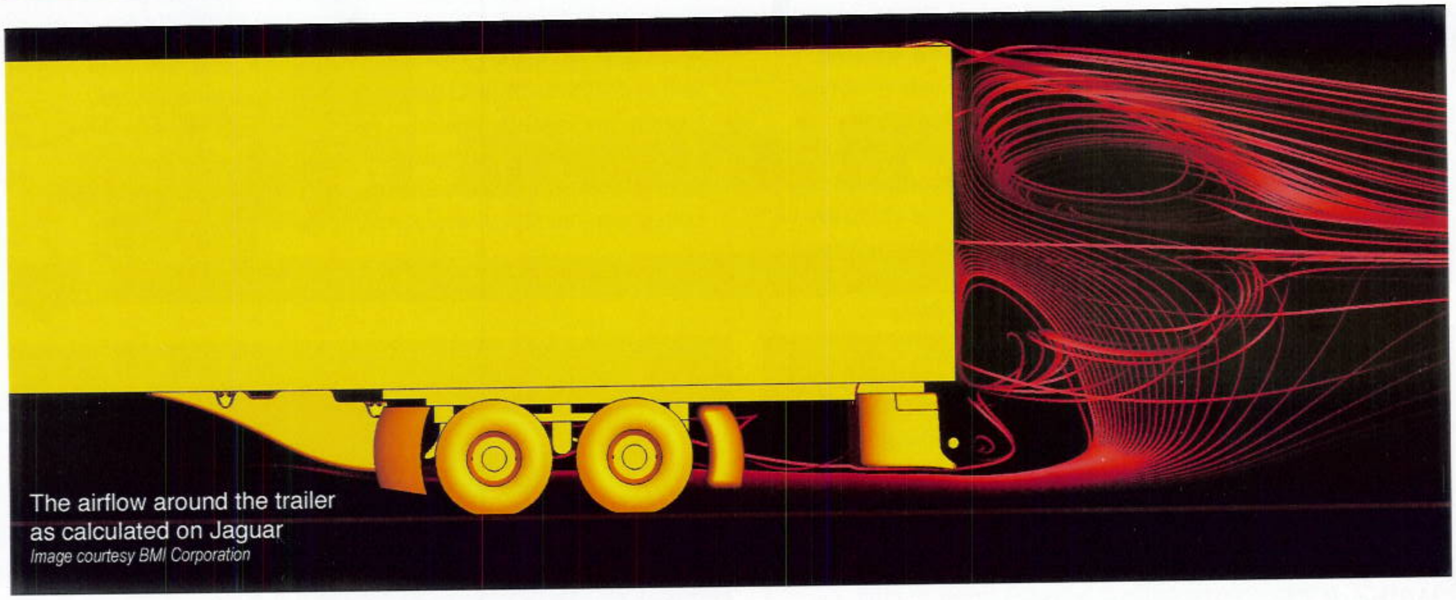
BMI was, as they say in computer industry jargon, compute-bound. Its engineers needed orders of magnitude additional computing capability, both to run highly detailed, accurate models of the trailer retrofit components, and get the results in time to meet the looming CARB deadlines.

The designed kit to improve aerodynamics and fuel mileage is shown in red *Image courtesy BMI Corporation*

Hunting a Jaguar

At the recommendation of some aerospace colleagues, BMI approached the Oak Ridge Leadership Computing Facility at the Department of Energy's (DOE) Oak Ridge National Laboratory in Tennessee. Through the laboratory's Industrial HPC Partnerships Program BMI applied for, and received, access to the extraordinary computational capabilities of the Jaguar high performance computer.

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 ample to provide BMI with all the computational power it needed. (A petaflop is a measure of a computer's processing



The airflow around the trailer as calculated on Jaguar
Image courtesy BMI Corporation

speed and refers to a thousand trillion [one quadrillion] floating point operations per second.) In addition, BMI opted to run the FUN3D application, NASA's computational fluid dynamics (CFD) software that is used widely in the aerospace industry.

Access to Jaguar allowed BMI to design a unique UnderTray System, a group of aerodynamic add-on parts that minimizes drag associated with the trailer's underside components. The Under Tray 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 BMI was using before moving to Jaguar, running a model of a typical UnderTray component might take four days and use every resource the cluster had to offer. Jaguar allows the BMI engineers to break the truck into literally hundreds of pieces in order to calculate drag with a high degree of accuracy.

Says John Anastos, BMI 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 allows 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."

Design Digitally, Confirm Physically

Access to Jaguar lead BMI to the Holy Grail 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.

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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 as much – you can't see the flow and take it apart like you can with a CFD solution. So we develop our designs computationally, and then confirm them physically through testing to be sure we haven't 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 BMI 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.

"We were pleased to see how close our CFD simulations match the physical test results," says Henderson. "The process works – physical test results were within one 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."

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Mike Henderson, CEO, BMI Corporation

The EPA SmartWays program has certified the UnderTray system components with a 6.8% 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% 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 U.S. could annually save almost 1.5 billion gallons of diesel fuel; reduce CO_2 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 only matter if they generate hard cash. The power of Jaguar has allowed BMI to use its aerospace and race car design expertise to turn leading-edge aerodynamic designs into market-ready, retrofitable products for the trucking industry. And they were able to do it at an unprecedented pace – a mere nine months. By bringing products to market faster, BMI will realize revenue earlier and move into a leadership position in a new industry. With this early-to-market advantage, the company should capture even greater market share, increasing its revenue opportunity.

Next Steps

BMI Super Truck concept
Image courtesy BMI Corporation

The first production UnderTray products will be installed on fleets owned by BMI customers Frito-Lay, Swift Transportation, and Conway Truckload, permitting their 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, BMI 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.

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