High Performance Computing

Case Study.

From Safety Performance to EcoBoost Technology: HPC Enables Innovation and Productivity at Ford Motor Company

Compete.
Council on Competitiveness

The Council on Competitiveness is a nonprofit, 501 (c) (3) organization as recognized by the U.S. Internal Revenue Service. The Council's activities are funded by contributions from its members, foundations, and project contributions. To learn more about the Council on Competitiveness, visit our home page at www.compete.org.

Design: Soulellis Studio

This work was supported by DARPA contract number FA8750-08-C-0184.

Printed in the United States of America.

Ford Motor Company

From Safety Performance to EcoBoost Technology: HPC Enables Innovation and Productivity at Ford Motor Company

Compete.
Council on Competitiveness

Ford Motor Company

Ford offers distinctively designed vehicles for the world's varying lifestyles. From the Model T—the car that first brought driving to the people—to more recent favorites like the Mustang in the United States, the Mondeo in Europe, the EcoSport in South America and the Territory in Asia, Ford vehicles are among the world's most popular cars, trucks and SUVs.

http://www.ford.com/

EcoBoost Engine

Challenges

- Lead innovation in the global automobile industry
- Advance passive and active safety measures
- Address complex technical problems virtually for product development, manufacturing, performance and fuel economy
- Create optimal designs early on, reducing late design changes and increasing product development efficiency
- Maintain a healthy balance between the level and availability of computing power

Solutions

- Model whole vehicles to evaluate multiple attributes
- Use HPC to analyze effectiveness of passive and active safety, such as airbag performance and collision avoidance
- Perform combustion analysis to optimize fuel-air mix and fluid flow in engine
- Use analytical validation to reduce churn
- Evaluate the company's computing needs yearly and include upfront in business plan

HPC's Impact—Return on Investment

- Able to bring new products to market faster combining the use of more advanced modeling for testing
- Lessons learned and closed-loop processes enable quicker design turn around
- Expanded the "hybrid arena," increasing virtual capability with physical correlation
- Reduced modeling time with HPC by allowing the teams to try multiple scenarios, evaluate attribute trade-offs quickly, and determine optimal and creative solutions early in a program
- HPC has become a key tool enabler for product development to deliver quality, innovative products faster, meeting the time-to-market customers expect

From Safety to EcoBoost: HPC Enables Innovation and Productivity at Ford Motor Company

After an intense 30-year working relationship with supercomputers–ranging from early water-cooled Crays to today's commodity clusters–engineers at the Ford Motor Company view modeling and simulation with high performance computing (HPC) not as a high-tech miracle, but as an integral part of the business.

Ford's executive technical leader for global computer-aided engineering (CAE) and chief engineer for global materials and standards engineering, Nand K. Kochhar, says: "The combination of HPC and CAE simulation technology is a key enabler of our product development process. We provide advanced computational capabilities for Ford not just as a service, but as an integrated enabler of company business strategy. HPC is key to delivering on our overall business plan; optimizing product development, creating high quality products and improving time-to-market. With advances in computing technologies, it is possible to accomplish this in a cost-effective manner."

The Ford Motor Company, based in Dearborn, Mich., manufactures and distributes automobiles in 200 markets across six continents. With about 201,000 employees and 90 plants worldwide, the company's core automotive brands include Ford and Lincoln.

Kochhar dates Ford's involvement with HPC back to the 1980s, the early days of the supercomputer industry. The company's first machine was from Control Data Corporation, one of the original supercomputer leaders, before moving to an early Cray, the X-MP, which was the world's fastest computer in the mid-1980s. Ford stayed with Cray systems along with solutions from SGI, IBM and Digital/Compaq through the 1990s and was among the leaders in adopting commodity Linux cluster technology as it became available at the turn of the century. Today the company uses a mix of HPC clusters based on x86-64 processors supplied primarily by IBM and HP, along with commercial applications software for its CAE applications–a move that has substantially reduced the need for in-house software development.

Figure 1: Ford Fusion hybrid vehicle, 2010 Motor Trend Car of the Year.

Alex Akkerman, Ford's senior HPC technical specialist, points out that even though the clusters are located in two separate data centers: "We operate the various systems as one monolithic virtual environment–our internal customers interface with it as if it is one system. Although we have many touch points within Ford's IT organization, our group, made up of a dozen or so people, is an independent entity specifically dedicated to the HPC environment. The vast majority of the work that runs on our HPC resources is CAE-based analyses."

Akkerman says that the demand for HPC services by their in-house customers–Ford's cohort of engineers and designers–is insatiable. "We add capacity based on our customer's requirements and normally upgrade the systems at least once a year. But the users tend to very quickly use up whatever we've installed, so deploying new HPC resources has become an ongoing process. Our hardware utilization is about 85 to 90 percent of capacity, which is as high as we can go without affecting our key metric, job turnaround time. Our primary service level objective is to manage our resources to provide optimal and predictable time-to-solution. This is in line with the company's business objective of constantly reducing time-to-market to make Ford more competitive in world markets."

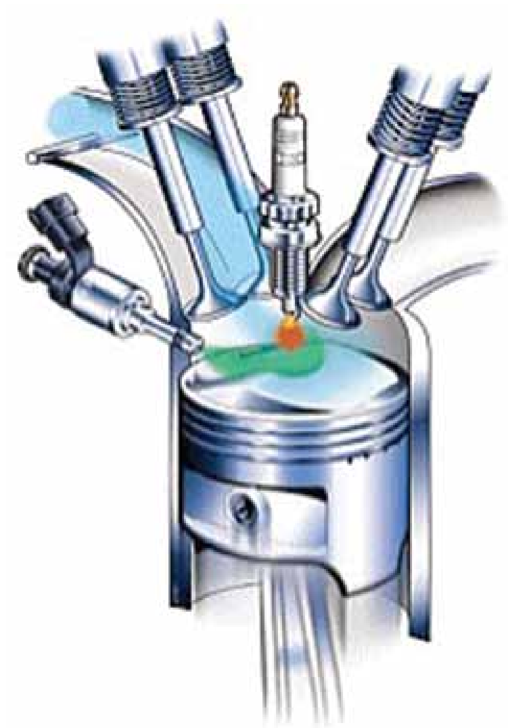

Figure 2: EcoBoost—with direct injection, fuel is injected into each cylinder of an engine in small, precise amounts.

Better Fuel Economy, Safer Rides and Quieter Cabins

Just a few examples of key initiatives that rely on the company's extensive HPC computational resources include: fuel economy and Ford's EcoBoost engine technology; safety, always a prime attribute at Ford; and internal cabin noise, a major factor in consumer satisfaction.

HPC and CAE played a pivotal role in the development of Ford's EcoBoost engine technology, which will be available in more than 80 percent of Ford vehicles by 2013. Today, 3.5-liter V-6 EcoBoost engines are available in the Lincoln MKS, Lincoln MKT, Ford Taurus SHO and Ford Flex. The new 2011MY Ford Edge is available with the new 2.0-liter 4-cylinder EcoBoost engine. That same engine will also go into the next-generation Ford Explorer, going into production in late 2010.

The EcoBoost family of 4-cylinder and 6-cylinder engines uses turbocharging and direct injection technology to achieve a 15-20 percent increase in fuel economy when compared to other mid-size utility vehicles.

Ford's Powertrain team used HPC technology along with computational fluid dynamics (CFD) and CAE applications to optimize the design of the EcoBoost. In particular, the engineers worked on optimizing combustion and structural aspects of the EcoBoost powertrain technologies.

"EcoBoost is truly a smart solution for consumers because it provides both improved fuel economy and superior driving performance," Derrick Kuzak, group vice president of Global Product Development, says. "The combination of turbocharging and direct injection allows smaller engines to act like larger ones while still delivering the fuel economy of the smaller powerplant."

"A lot of HPC-based computational analysis is involved in simulating the trade-offs between performance, shift quality and fuel economy. In the case of the engine, we conduct combustion analysis—optimizing a fuel-air mix,

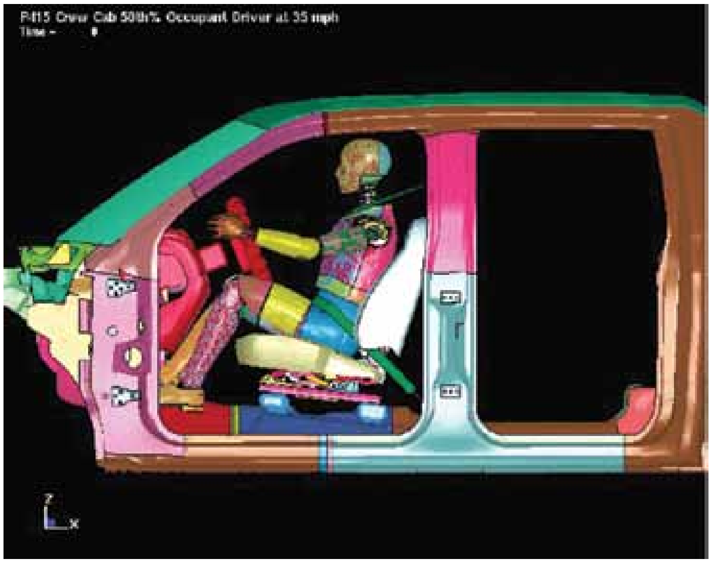

Figure 3. Safety—virtual Crash simulations of structural and passive restraint performance.

for example. And to develop overall vehicle fuel efficiency, we use CFD calculations to compute the optimal aerodynamics of the proposed vehicle," Kochhar says.

HPC resources are also used to develop both passive and active safety attributes. Passive safety focuses on improving structural performance and airbag deployment to reduce intrusion into the vehicle and help protect the occupants. Ford's active safety initiatives include Adaptive Cruise Control and Collision Warning with Brake Support, which uses radar to detect moving vehicles directly ahead. When the danger of a collision is detected, the system warns the driver, automatically pre-charges brakes, and engages a brake-assist feature that helps drivers quickly reach maximum braking once the brakes are engaged. The technology was introduced in the summer of 2009 on the 2010 Ford Taurus, Lincoln MKS sedan and Lincoln MKT crossover, and will be made available on other Ford vehicles.

The entire vehicle is modeled to assess both the active and passive safety designs. Engineers simulate the results of crashes based on a wide variety of design and environmental factors without actually building a physical prototype for testing.

HPC is also used to model what is known internally as "NVH"—noise, vibration and harshness. Controlling interior noise in the automobile is a major factor in customer satisfaction. As Kochhar notes: "In some of our products, like the Mustang, we want that powerful sound to come in, so we need to tune the powertrain accordingly." HPC comes into play because of the computing complexity involved in allowing a certain amount of noise to come into the cabin while at the same time minimizing noises generated by the road, wind and the vehicle's powertrain, all of which are influenced by the driving dynamics of the vehicle. "These are complicated interactions that take a large amount of computational resources to deliver an optimum design," he says.

From the Physical to the Virtual

Over time, HPC has allowed Ford's engineers to perform increasing amounts of virtual road testing and wind tunnel simulations, and reduce the company's reliance on physical prototyping, resulting in the ability to bring more new products to market faster and with higher quality.

"HPC modeling and simulation is allowing us to deliver the time-to-market with the advanced designs our customers have come to expect," Kochhar says. "We want fresh products showing up in our showrooms more quickly than we have in the past. Using simulation rather than relying heavily on physical testing allows us to shorten product development cycle times. Instead of building full-scale physical prototypes at every step in the development process and subjecting them to actual road testing as well as crash and wind tunnel tests, we can now use computational capabilities to get many of the results needed. We still use physical testing to validate our HPC-based results, but over the years we have become very proficient in offsetting the physical build technologies with analytical technologies.

"Not only does this reduce costs; it allows us to bring more robustness, quality and creativity to vehicle designs," he continues. "The flexibility and speed made possible by HPC lets us simulate a wider range of scenarios, component combinations and associated trade-offs than would have been possible with physical testing. The result is that over the years, with continuous improvements in technology, we have been able to maximize creativity while reducing product development costs dramatically."

Simulations help engineers reduce the number of costly design level changes on any given component. With HPC, the number of changes to parts are kept to a minimum by providing a level of analytical validation of functional requirements and performance factors early in the development process. Then, when a final verification of the design is conducted using physical testing, the product has a greater chance of being successful due to all the analytical testing and virtual design modifications that have taken place up front. "If our prototype vehicle does not pass our rigorous tests at the end of the development process, we follow what's called a 'closed loop lessons learned process' to see if we need to update some of the assumptions in our computer models," Kochhar adds.

This continuous improvement process is being used to help Ford realize its overall electrification strategy in the development of hybrids and battery powered electric vehicles. Using HPC, materials simulation, weight optimization and systems modeling is possible, improving the quality and design of greener vehicles. Included is the use of recyclable materials—the 2008 Ford Mustang, for example, was the first automobile Ford introduced with soy-based foam seating.

"At Ford, HPC is a strategic enabler of our product development process and an indispensible tool for continuous innovation," Kochhar concludes. "The technology allows us to build an environment that continuously improves the product development process, speeds up time-to-market and lowers costs. HPC is an integral part of Ford's competitiveness in a very tough marketplace."

About the Project

This case study was produced as part of a project that was created to demonstrate the business and competitive value of modeling, simulation and analysis with HPC in the U.S. private sector, motivate usage of this innovation-accelerating technology throughout the DoD's supply chain, and identify technologies and partners that can help support an HPC infrastructure for the DoD supply chain base. It was led by the University of Southern California's Information Sciences Institute (ISI) and supported by funding from the Defense Advanced Research Projects Agency (DARPA) under contract number FA8750-08-C-0184. DARPA is the central research and development office for the U.S. Department of Defense. DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security. For more information, see http://www.darpa.mil.

Complete information about the other case studies and pilot programs associated with this project is available at http://www.compete.org/hpc/darpapilots/.

Council on Competitiveness
1500 K Street, NW, Suite 850, Washington, D.C. 20005 T 202 682 4292
Compete.org

Compete.

Council on
Competitiveness