

Case Study.

Whirlpool's Home
Appliance Rocket
Science: Design
to Delivery with
High Performance
Computing



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Design: Soulellis Studio

Printed in the United States of America

Whirlpool's Home Appliance Rocket Science: Design to Delivery with High Performance Computing

Virtual product development using in-house supercomputing capabilities has allowed Whirlpool Corporation to take a systems approach to designing not only its broad and varied line of appliances, but also the packaging that protects the products during shipping. High performance computing at the company is operating in a full-fledged production environment, delivering significant payback. Top management regards Whirlpool's supercomputing capabilities as a key strategic asset.

What do supersonic aircraft wings have in common with washing machines? Both, it turns out, are designed with the help of powerful high performance computing (HPC) systems. But, as the engineers at Whirlpool Corporation would argue, the difficulties of designing a wing—no simple task—pale in comparison with the complexities of designing kitchen ranges, refrigerators, washers, dryers and other home appliances.

“The problems we tackle on a routine basis are easily as complex as those faced by designers in the aerospace industry,” says Tom Giolda, the company's engineering director for global mechanical structures and systems. “I know, I used to work in aerospace. Determining the properties associated with combustion in our gas ranges or the dynamics of fluids in a dishwasher is every bit as difficult as designing optimum rocket fuel or creating a new aircraft wing, perhaps even more so. And we may manufacture five million or more such appliances. We also operate in a highly competitive environment—our appliances have to delight our customers and make a profit for the company—if we make a mistake, the economic consequences can be severe.”

Headquartered in Benton Harbor, Mich., Whirlpool is the world's leading manufacturer and marketer of major home appliances, with annual sales of approximately \$19 billion, 73,000 employees and 72 manufacturing and technology research centers around the world. The company markets Whirlpool®, Maytag®, KitchenAid®, Jenn-Air®, Amana®, Brastemp®, Consul®, Bauknecht® and other major brand names to customers in nearly every country around the world. The company faces significant international competition from manu-

facturing giants LG (South Korea), Electrolux (Sweden) and Samsung (South Korea), in addition to U.S.-based General Electric.

Home Appliance “Rocket Science”

Whirlpool is continuously creating new product designs, and each design has numerous variations. Their design process begins by listening to customers to determine the features they want built into the product. At the same time, Whirlpool must take into account regulatory requirements, as well as meet company cost and quality targets. Giolda explains, “For example, the design criteria for temperature variations within a refrigerator are very strict—you don't want frost forming on the inside of the unit or condensation on the outside—so we do a good deal of modeling up front to make sure that we get good performance.”

And, because these appliances are destined for a customer's home, a host of safety issues must also be addressed. For example, if a small child weighing 45 pounds or so sits on the door of a front-loading dryer, the appliance should not tip over. Giolda notes that their engineers must also be concerned with such things as fire containment in dryers and Underwriters Laboratories (UL) requirements. “We're dealing with massive complexity,” he says. “For instance, a side-by-side refrigerator may have three or four hundred different SKUs.”

The Problem of Packaging

In addition to the complex design parameters associated with their products, Whirlpool has another, seemingly



With HPC, Whirlpool is able to model, simulate and analyze (e.g., CFD, FEA, etc.) their products as complete systems, as in this image showing a refrigerator master assembly, including packaging material for transportation.

mundane, but equally complex and pressing problem—reducing damage to the product and its packaging during transit from the factory floor to its eventual destination inside the consumer’s home. This journey through the supply chain can provide some unpleasant surprises for the appliance and its protective packaging.

As they make their way from the manufacturer to the distribution center, then on to the retailer and finally into the customer’s home, the packed products may undergo a number of indignities. They can be dropped, squeezed, stacked, crushed, vibrated, shocked and/or subjected to extremes of heat, cold and humidity. For example, a forklift—known as a clamp truck—can close its metal jaws around a boxed appliance with 2,000 pounds of pressure. An appliance can be clamped and moved up to

29 times as it wends its way through the supply chain to its final destination. These products can cost thousands of dollars. So, if an appliance or even its packaging is damaged in transit, the retailer or customer may refuse to accept delivery. Thousands of dollars just went down the drain.

Traditionally, manufacturers have focused on reducing the cost of the cardboard, plastic and foam packaging designed to protect products in their travels. However, Giolda and his engineers and members of the company’s supply chain management came to the shared realization that the appliance and its packaging have to be considered as a single system. “Each ‘product-packaging system’ has its own unique set of design, safety, durability and regulatory requirements that have to be examined and optimized,” Giolda continues. “So we needed a way to meet those requirements without having to build a whole series of physical units and run tests on them until we found the right combination of design elements. We don’t have the time or the money to do that kind of physical prototyping—it would kill us competitively.”

The alternative was to conduct virtual product development, simulating and modeling to create this integrated system. To do this, Whirlpool realized it needed a lot more processing power than was currently available on the engineering organization’s desktop workstations.

Taking the HPC Plunge

So, in 2004, Whirlpool first dipped its toe into the super-computer waters with the purchase of a small HPC “cluster” system composed of 48 processors. Within a year and a half, this cluster was overwhelmed. The company then invested in a more powerful high performance system built around 168 processors. Today, this machine is logging 90 percent utilization and running 24/7 to meet the company’s modeling and simulation needs.

Using HPC, Whirlpool models product designs computationally in “virtual space,” exploring a wide variety of permutations and conducting tests using simulation. When designers finally do build the physical prototypes, they use them for validation, not development. “By designing in virtual space, we are getting first pass success,” Giolda notes.

“Moving off the desktop and on to HPC systems...was a turning point for Whirlpool.”

Tom Giolda, Engineering Director for Global Mechanical Structures and Systems, Whirlpool Corporation

For example, a computer simulation of how washers were being handled inside the company's manufacturing plant and distribution center disclosed that the clamp trucks sometimes put too much pressure on the packaged goods. Also, the big squeeze was not distributed evenly over the container and its contents—engineers found that the lower corner of the washer was taking the lion's share of the pressure. As a result, the clamps were redesigned to better distribute the pressure, and a tough cardboard strut was added to the packaging for added protection.

Members of the mechanical structures and systems engineering team are also using the company's super-computing resources to investigate thermal management inside some of Whirlpool's products. “We're answering some very simple questions that have significant economic impact,” Giolda says. “For example, by moving thermostats from the right to the left hand side of a refrigerator, we are able to realize significant savings in the cost of the wiring harness. We also save by designing a common sensor and thermostat wiring harness for both a gas and electric range.

“Given the rapidly rising cost of oil and electricity, we're using HPC to make our appliances more energy efficient,” Giolda continues. “For instance, we run thermal simulations on our products to determine how much waste energy we can capture and recycle into the system. We are modeling the effectiveness of reflective films on the windows inside oven cavities, the efficiency of different methods of heat shielding, and ways of achieving better ventilation to reduce overheating—to name just a few design solutions we are investigating. None of this would be possible without high performance computing.”

HPC's Competitive Impact: Innovative Designs, Happier Customers, Market Success

Says Giolda, “Moving off the desktop and on to HPC systems capable of parallel processing was a turning point for Whirlpool. Essentially, it has allowed us to perform virtual product development and build appliances that are a big hit in the marketplace.”

HPC allows the Whirlpool engineers to run more complex simulations and do them faster. In addition, engineers are now beginning to run stochastic models in order to better predict how a product or material will function in the real world, and optimize the design accordingly. Stochastic modeling, also known as the Monte Carlo method, tests sensitivity to multiple variations of a single characteristic, such as temperature or pressure, and creates a probability distribution of that sensitivity. For example, a stochastic model may test the durability of packaging materials to temperatures ranging from sub-zero to 100 degrees F, in one-degree increments, and forklift pressure from 1,000-2,000 pounds in one-pound increments. Such detailed modeling allows engineers to identify critical characteristics that can lead to more robust and salable products.

HPC also has allowed Whirlpool to substantially replace much of its physical prototyping with virtual (i.e., computational) prototyping. “Testing using virtual prototyping has for the most part replaced physical testing—we're no longer using the old ‘heat and beat’ approach,” says Giolda. “We will never eliminate all physical prototypes because we have to put a product in peoples' homes to test their response to it. However, by basically debugging these units before they are shipped, we can reduce engineering churn.”

HPC horsepower is also enabling the successful design of products and packaging as an integrated system. Instead of trying to determine why a certain type of packaging failed to protect a product after the damage has occurred, Whirlpool can now provide design specifications to its suppliers up front to prevent these failures before they happen. “It's working,” says Giolda, “because our quality numbers are improving and product returns are down.”

Reliance on virtual prototyping has also stimulated cultural and operational changes within Whirlpool that are generating productivity gains. To facilitate the design of new products and their associated packaging, the company's global, virtual and physical design organizations, once separate, have now been merged into a single entity. "They are going through a tremendous learning experience about each other," Giolda explains. "And the net result is that our engineers are becoming better analysts, and our model builders are starting to understand a little bit more about the virtual side. So you're seeing some cross-fertilization.

"To sum up, the number one benefit that we've realized by getting off the desktop and on to a supercomputer is customer satisfaction," says Giolda. "If you're laying out \$1,500 for a washing machine, it had better work

the way it's expected, and it should come off the truck in pristine condition. Number two is a ramp up in our ability to surprise and delight our customers with new and innovative design features and product enhancements—we are able to provide them with the best possible value for their dollar. Finally, we help Whirlpool stay out in front of the competition and make some money in the process.

"When we were building the business case for high performance computing back in 2004, we had some pretty high payback hurdles to navigate," he concludes. "We had to promise that if management gave us the dollars, we would return a specified savings in that very first fiscal year. Well, we delivered on that promise, and we continue to do so." The result is that within Whirlpool, at the very highest levels, supercomputing is viewed as a key strategic asset.

In Brief

Key Challenges

- Find the design "sweet spot" within complex and sometimes conflicting customer, safety, regulatory and cost requirements
- Reduce customer returns and the associated revenue loss incurred from products and packaging damaged in shipment
- Decrease costs and time-to-market delays associated with physical prototyping

Solutions

- Create a highly effective virtual design space, where engineers can model advanced design solutions (including multiple requirements) and run these more complex simulations faster
- Model and simulate products and corresponding packaging as an integrated "system" that withstands shipping rigors and arrives undamaged

Key HPC Benefits

- Uses stochastic modeling to simulate and test more products and their many variations in a virtual design space before committing to a physical prototype leading to fewer, more accurate prototypes and reduced costs
- Saves time and money because prototypes are used for validation, not development
- Improves customer satisfaction due to higher quality products that include more customer design features
- Saves millions of dollars every year because packaging and product design innovations substantially reduce shipping damage, resulting in fewer product returns
- Reduces product cycle time, resulting in faster time to market
- Creates competitive advantage over other appliance manufacturers that also use modeling and simulation in their product development

Web Site

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