High Performance Computing

Case Study.

High Performance Computing Helps Create New Treatment for Stroke Victims

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Medrad, a provider of drug delivery systems, MRI imaging accessories and catheters, had purchased patents for a promising interventional catheter device to mechanically remove blood clots associated with a stroke. Breaking with a long tradition of building numerous physical prototypes to research the potential of a new technology, Medrad turned to the NSF-funded Pittsburgh Supercomputing Center, experts at Carnegie Mellon University and the use of complex numerical simulations running on high performance computers to determine if the catheter technology was worth pursuing. It was.

What do a bowl of jello and high performance computing (HPC) have in common?

Both play a role in the development of a medical device that could significantly improve the treatment of stroke victims.

When someone has a stroke, the faster they can be brought to the hospital, the better. Doctors have a small window in which to introduce drugs into the patient's circulatory system in order to break up the clot – any delay can lead to paralysis or death.

About five years ago, two engineers developed a prototype device that would speed up treatment by mechanically breaking up clots in the brain or elsewhere in the body. As part of their research and development, they used Jell-O to simulate the physical properties of the brain.

The work on this interventional catheter technology came to the attention of Medrad, Inc., of Indianola, PA. Medrad is a leader in providing medical devices and services that enable and enhance diagnostic and therapeutic imaging procedures in the human body. An affiliate of Bayer Schering Pharmaceutical AG, Germany with annual revenues of around $500 million and 1700 employees, Medrad's diagnostic products have captured 70 percent to 80 percent market share. The company wants to expand its business by moving into the interventional applications market.

Making a Timely and Cost-effective "Go" or "No Go" Decision

"The patented prototype device seemed like a good fit with Medrad's growth objectives, so we purchased the rights to the technology," says John Kalafut, principal research scientist at Medrad. "But before we could give the go-ahead to proceed with product development, we had a number of practical questions that needed answers, and we needed them quickly."

The task of getting those answers fell to Kalafut and Medrad's R&D organization. The R&D group's mission is innovation – find new technologies, address new clinical problems and develop new solutions to support Medrad's business goals. A major part of that effort is to determine in a timely manner if a potential technology is actually feasible – will it work and, if so, what are its limitations?

"We want to make those decisions before we commission expensive product development activities involving our marketing people and design engineers," Kalafut says. "Because we examine many different opportunities each year, we need to be able to quickly gauge the technology's efficacy and either start the development process, or turn it down and move on to the next. If the technology looks promising, we make an initial commitment and then, several years later, launch a multimillion dollar project to commercialize it."

While the R&D group felt the proposed catheter device had promise, it needed to determine the extent of the engineering required to turn it into a viable product. "We needed to demonstrate to ourselves that the catheter would work the way the inventors said it would, that the interventions were robust, and that we could test a variety of repeatable conditions," Kalafut explains.

The classic approach to researching a potential biomedical product involves making bench-top models, subjecting each one to a variety of trial conditions and then moving into animal and human testing. But this approach could not efficiently capture the complicated interactions between the blood cells, the vessel walls, the clot and the device itself. Kalafut felt that the catheter project was an excellent opportunity to take a new approach: replace the traditional build-and-test process with numerical simulations, both to establish if the catheter would really work and then to examine a variety of parameters to determine the optimal design solution. "Not only did we need to understand the physics of how the device worked, we also wanted to explore different design and manufacturing approaches," says Kalafut. "We felt that doing this computationally would be more efficient and faster than building lots of different physical prototypes."

The physics involved with a blocked circulatory system and the interventional catheter device includes complex fluid dynamics that can be represented mathematically – so-called computational fluid dynamics (CFD). In particular, the group wanted to use the powerful algorithms associated with CFD to establish if the catheter would break up the blood clots as claimed. However, the R&D group's high-end workstations lacked the horsepower to conduct the complex simulations. They also did not have the in-house expertise required to develop the detailed CFD codes needed for this kind of investigation. They needed access to HPC and software, and the expertise to help them harness its full potential.

Two other challenges facing Kalafut's group had less to do with technology and more to do with tradition and individual mindsets. Some of the company's engineers who had been building prototypes for decades felt that computer simulation just wouldn't work – you had to build something real, something tangible, not just work with a bunch of equations.

The other related challenge was explaining the value proposition of HPC to upper management, including making a case for a robust ROI through the use of supercomputers at the nearby Pittsburgh Supercomputing Center (PSC) and the expertise of the Institute for Complex Engineered Systems at Carnegie Mellon University (CMU) and Ender Finol, Ph.D. Some top managers felt it could be a waste of time to work with a university and supercomputer center – it would be too expensive and might not produce anything practical.

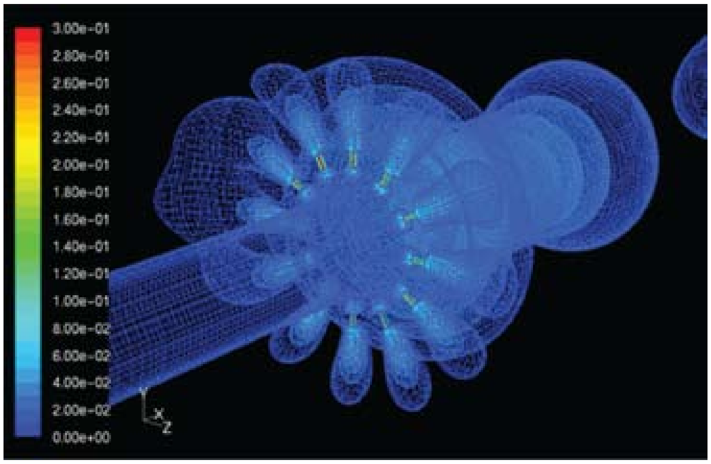
Busting Blood Clots with High Performance Computing

Kalafut and the R&D group prevailed. They convinced management that using HPC was essential to determining if the device would work, if it could be commercialized, and to answering these questions quickly enough to capture first-to-market advantage if Medrad wanted to move forward. CMU, PSC and supercomputing became part of the research and development process.

PSC is a joint effort of Carnegie Mellon University and the University of Pittsburgh together with Westinghouse Electric Company. It is one of a number of university supercomputing centers supported through the National Science Foundation to provide HPC capabilities to organizations across the country. These HPC centers are helping American businesses and institutions use supercomputing to promote innovation in order to be more competitive in the world marketplace.

Medrad used HPC at two critical points in their research and development. Initially, it was employed to investigate the physics of the catheter intervention device in relation to the blood vessels (vasculature) where a clot had to be broken up or removed. In other words, Medrad used HPC to simulate the process of the catheter destroying the clots, adjusting the parameters again and again to ensure that the phenomenon was repeatable. This validated that the science behind the patent's theory was solid and that the device would do what its inventors claimed. Then HPC was used to mathematically refine the prototypes by simulating many different combinations of changes – more than could be done physically in the time frame or budget available – to arrive at the best design. "Using the PSC supercomputer," Kalafut says, "we have been able to look at multiple iterations of

Simulated flow field from the prototype device as computed by 3D Computational Fluid Dynamics software at PSC. Image coutesy of Medrad, Inc.



different design parameters without building numerous, expensive prototypes."

Building on the success of the supercomputer CFD studies, a team from the research group and one of the business units now has demonstrated the viability of the device in repeated animal studies. As a result, Medrad is confident that they can manufacture the device.

HPC Competitive Impact: Validate, Illuminate, Accelerate, Save Lives

HPC allowed the Medrad research team to demonstrate the validity and value of the catheter technology much faster by confirming computationally (as compared to building and testing physical prototypes) that it could destroy the blood clots as claimed. In general, the Medrad research team needs to determine quickly if a technology is viable and, if not, shut it down saving time and money – what they call "fail fast." In the case of the catheter project, the positive results from the HPC simulations convinced Medrad management that they were receiving value from the purchase of the patents and gave them the confidence to make the next level of investment to accelerate the R&D process and refine the physical prototype.

Medrad researchers, including Marty Uram and David Wang, Ph.D., also gained new insights while reducing their costs when they used HPC to explore various design parameters through a "sensitivity analysis." In this process, Medrad mathematically varies a number of design parameters in a logical sequence to determine how robust the "clot busting" phenomenon is in response to those changes. The researchers are able to run far more permutations numerically as opposed to building different physical prototypes for each iteration, resulting in a more refined design. For the catheter technology, Kalafut estimates that supercomputing allowed them to cut eight to ten months off the development process, a huge savings in time and money that eventually also will translate into life-saving benefits for stroke victims.

As other development groups within the company see the tangible results that HPC is bringing to this project, they are becoming persuaded that HPC can help them with their projects, too. "We have demonstrated that the benefits we receive from tapping into these HPC resources extend beyond the catheter technology project," Kalafut says. "HPC allows us to tackle projects that were otherwise beyond our reach and has streamlined and optimized our production processes in new ways that translate into lower costs and higher productivity."

Finally, HPC is becoming a competitive imperative. "Many of our competitors are using modeling and simulation," Kalafut notes. "So for us to compete effectively, we have to adopt these tools as well." And the HPC resources and expertise available through the Pittsburgh Supercomputing Center and Carnegie Mellon University are providing the edge Medrad needs. "This program wouldn't be where it is today if we weren't partnering with PSC and CMU…We'd probably be a year away from still determining feasibility," Kalafut says. In a highly competitive global market, a year can be the difference between market success or failure. But ultimately, the real benefit is the availability of new technology and advanced medical products coming to market in a more timely fashion and giving new hope to stroke victims.

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John Kalafut, principal research scientist, Medrad, Inc.

In Brief

Key Challenges

- Explore the validity and accuracy of the claims associated with new technology and its potential for manufacture in a more timely and cost effective manner
- Get to a "go" or "no go" decision quickly and efficiently
- Overcome management and other development group resistance to supplementing traditional product R&D techniques with numerical modeling and simulations made possible by high performance computing (HPC)
- Make a case for HPC's return on investment

Solutions

- Tap into the HPC systems at the Pittsburgh Supercomputing Center and the expertise of scientists and engineers at the Carnegie Mellon University Institute for Complex Engineered Systems to supplement inhouse resources
- Use HPC simulations to validate that the proposed catheter technology would in fact work successfully
- Use HPC to examine multiple iterations of the catheter design rather than build a great quantity of physical prototypes

Key HPC Benefits

- Validates that the catheter technology would work without building multiple, expensive prototypes
- Optimizes prototypes numerically rather than taking the traditional build-and-test approach, saving time and money
- Saves eight to ten months in the R&D process
- Demonstrates the scientific and cost saving advantages of using high performance computing to management and other development groups
- Allows Medrad to be more competitive and enter new markets

Web Site

- www.medrad.com

Instead of using 100% virgin paper, we used paper that has been 30% Post-Consumer Recycled and made with 100% wind-generated electricty. We saved:

5 trees preserved for the future
1667 gal of water flow saved
276 lbs of solid waste not generated
509 lbs of greenhouse gasses prevented
3 million BTUs of energy not consumed

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