Conference Report

First Annual
High Performance Computing Users Conference

Supercharging U.S. Innovation & Competitiveness

July 13, 2004, Washington, D.C.

Council on Competitiveness

Cover Story:

The Council on Competitiveness thanks Tom White, of tomwhite.images-illustration & design, New York, NY, for the cover illustration which will be used throughout the Council's High Performance Computing Initiative.

It depicts and embodies the human mind, spirit and visionary thinking behind countless innovations. This creative and competitive nature will continue to drive the way we think and invent.

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Table of Contents

Introduction

1st Annual High Performance Computing Users Conference, Washington, D.C., July 13, 2004

Today, with technology, talent and capital available globally the United States is facing unprecedented competitive challenges abroad. So how does the U.S. compete and prosper?

We strongly believe that innovation is the bedrock of America's competitiveness. It drives gains in productivity and market share that guarantee a rising standard of living for all Americans.

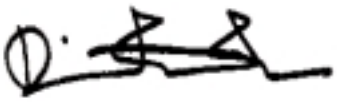
However, an economy built on innovation can only succeed if it has access to and uses the best tools to drive the innovation process. And there are few areas of technology that hold more promise for stimulating innovation and propelling competitiveness than high performance computing (HPC). Indeed, we believe that the country that out-computes will be the one that out-competes.

Yet, American businesses face a dilemma when it comes to the use of HPC to advance productivity and innovation. There's widespread recognition that both longtime and emerging HPC users face a variety of barriers to using this innovation-driving technology to its full potential.

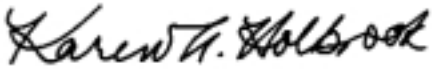
In order to better understand these barriers, and to begin a public-private sector dialog to address them, the Council on Competitiveness—in partnership with the Defense Advanced Research Projects Agency (DARPA) and the Department of Energy's National Nuclear Security Administration and Office of Science—convened the First Annual HPC Users Conference, in Washington, D.C., on July 13, 2004.

The conference was unique. During the course of a day, senior government officials responsible for HPC funding and development, experienced business HPC users, and senior academic HPC users—more than 200 participants in all—shared their experiences and vision through engaging interactive panels, keynote addresses, and whole group discussion. They provided inspiring examples of the productivity gains possible with HPC and the "grand challenge" HPC opportunities that American companies believe can fuel their competitiveness. And they frankly identified the business and technical barriers limiting their HPC use. Conference participants were able to put their discussion in context through hearing the results of the Council's first annual National HPC Users Survey.

The message from the day's proceedings was clear. If the U.S. is going to reach the heights at which new businesses and industries are created, we need the breakthrough insights that emerge from advanced HPC applications.



David E. Shaw
Chairman
D. E. Shaw & Co., Inc.



Karen A. Holbrook
President
The Ohio State University

Executive Summary

Executive Summary

1st Annual High Performance Computing Users Conference, Washington, D.C., July 13, 2004

The 1st Annual High Performance Computing Users Conference brought together more than 200 senior government, business and academic high performance computing (HPC) users and policy makers to discuss the enormous opportunities available from more widespread use of HPC, and identify the barriers limiting private sector application of this technology in America today.

The current focus on HPC and its linkage to economic competitiveness underscores the convergence of a number of powerful global forces. These include the commoditization of HPC technology, the globalization of business operations and lightning speed competition, and the recognition of the enormous potential of HPC to transform business functions, particularly in the large services sector, as well as in advanced manufacturing.

Senior government officials confirmed that HPC resources are essential to solving problems critical to U.S. national security interests, and organizations such as the Defense Advanced Research Projects Agency (DARPA) and the Department of Energy (DOE) play a critical role as investors and leading edge users. But the full benefits of advances in high performance computing have not been captured by the private sector.

This observation was amplified in the results of the first HPC Users Survey, released at the conference. The majority of businesses surveyed identified HPC as an indispensable innovation tool, but noted that their companies were not using HPC as aggressively as possible.

Conference panelists reinforced this message. They noted that HPC provides significant competitive advantage to current industrial HPC users. These advantages include reduced design and analysis R&D costs through virtual prototyping, shorter time to market, and even the creation of new industries, such as the digital animation sector. However, they emphasized that their companies need improved HPC resources to solve a range of currently intractable, major R&D problems, and thus meet growing international competition.

Barriers to private sector HPC use were identified in three key areas:

- *Business culture: In the boardrooms of many American companies HPC isn't seen as an innovation edge, but rather a cost of doing business with no clear idea of the actual return on investment.*
- *Educational: Many industries don't have the people who can productively use HPC to its full innovation potential.*
- *Technical: These include the essential need for easier-to-use HPC software and improved mathematical models.*

In summary, there was clear agreement on the transformational capabilities of HPC to enhance business productivity and boost national economic security. Key next steps proposed for supercharging U.S. innovation with HPC included: renewing and creating new government-industry-university partnerships, fueling next-generation HPC simulations, and improved linkage between the HPC skills and knowledge taught by universities and those required by businesses.

Building on the Conference momentum and findings, the Council on Competitiveness HPC Advisory Committee is creating an Action Agenda, including a focus on new 21st century government-private sector partnerships. Partnerships will form a key part of discussions at the 2nd High Performance Computing Users Conference, planned for July 13, 2005.

Conference Proceedings

Context: Innovation is Imperative

Image courtesy of HNTB.

Council on Competitiveness President Deborah L. Wince-Smith set the context for the conference with opening remarks that framed the event as part of the Council's broader innovation agenda. The ability of the U.S. to create, innovate and improve more rapidly than its global competitors will be the key to ensuring productive growth, and guaranteeing an increased standard of living for all citizens. "By shrinking 'time to insight' and 'time to solution' through the use of high performance computing, we can accelerate the innovative process in ways simply not seen in the past," Wince-Smith explained.

Conference Master of Ceremonies Dr. David E. Shaw, Chairman, D. E. Shaw & Co, Inc., and Cochairman of the Council's High Performance Computing (HPC) Advisory Committee, then framed the day's discussion by outlining the questions that the more than 200 panelists and attendees had gathered to discuss:

- *What are the linkages between HPC, national security and economic competitiveness?*
- *What are the current competitive advantages of HPC to America's businesses?*
- *How could the intractable challenges industries face today be solved by increased HPC power, and how would doing this benefit their companies' competitiveness?*
- *What are the barriers impeding access to HPC by U.S. businesses?*
- *What are possible solutions to these barriers?*

In thinking about these questions, Dr. Shaw encouraged all conference participants to consider particularly "the various ways that the public sector and the private sectors can work together to more effectively harness HPC's capability for our country's competitive advantage."

The Government View: National Security, HPC and Economic Competitiveness

What's the link between government investment in HPC science and technology and the economic competitiveness of America's businesses?

The Defense Department and the Department of Energy (DOE) laboratories under the National Nuclear Security Administration and the Office of Science have long driven advances in high performance computing by assuming risk, both as investors and users, which the private sector often cannot afford to take. As investors, they have supported cutting edge, public and private sector R&D critical to advancing this technology's development and ensuring that the U.S. remains a leader in designing and manufacturing HPC systems.

As committed "power users," they purchase the most advanced systems available to gain a competitive advantage in accomplishing their missions. And as they aggressively use HPC to solve complex problems vital to national security and basic science, they push and prove out the technology, often changing it along the way. Laboratories under DOE's National Nuclear Security Administration, for example, often have been the first to purchase new HPC systems, providing not only critical early revenue, but also important user insight to HPC developers. This valuable information exchange helps hardware and software developers refine their products, and has pioneered the way for more usable and affordable systems, enabling broader adoption of this technology across the private sector to propel innovation and competitiveness.

Dr. Anthony Tether, Director of the Defense Advanced Research Projects Agency (DARPA), pointed out that HPC resources are clearly a major competitive advantage for America's national security interests. "We know in the Department of Defense and the Department of Energy the role of large computers that enable us to model very large systems to the point that we really don't have to build them until the final stage, but instead we can simulate the entire system and tell what the performance is going to be," said Dr. Tether. "That gives the U.S., from a security viewpoint, a great competitive advantage over other countries."

Dr. Tether noted that DARPA is typically six-to-eight years ahead of industry in terms of information technology use, giving the agency an over-the-horizon perspective on HPC. DARPA's history includes a crucial role in the creation of the Internet, the first personal computer, and massively parallel high performance computing.

But the full benefits of these advances, particularly the most recent ones, have not been fully embraced by the private sector. This is not only crucial for businesses, but also for broader national interests in terms of ready and economical access to HPC technologies.

"The facts are that if these high performance computers don't end up having a commercial value, the business will go away," noted Dr. Tether. He added that this larger commercial application would only happen if "HPC is easy to use." He noted also that DARPA is indirectly addressing this through its current emphasis on high productivity computing, which stresses computational productivity rather than sheer processor speed.

Speaking later in the morning, Dr. Everet H. Beckner, Deputy Administrator for Defense Programs at DOE's National Nuclear Security Administration, reiterated the singular value of HPC to national security.

He pointed out that one of the longest running applications of HPC, as well as one of the most impressive demonstrations of its capability, is its application to U.S. nuclear stockpile maintenance under the Advanced Simulation and Computing (ASC) program. As a result of the Comprehensive Test Ban Treaty, the U.S has relied on the advanced modeling and simulation capabilities of the world's most powerful high performance computers to assure the safety and reliability of the U.S. nuclear arsenal.

"We're dedicated to telling the President that the nuclear weapons work. And this rests on the backbone of HPC," said Dr. Beckner.

In his keynote luncheon address, Dr. John H. Marburger III, Science Advisor to the President and Director of the Office of Science and Technology Policy, stressed that transferring government HPC advances to American businesses requires "more than ordinary vision." He reflected on the history of HPC noting that it has always required visionaries in science and business to see and capitalize on HPC's transformative potential.

He raised a cautionary note, however, pointing to a significant gap—analogous to an enormous competitiveness opportunity—between proven HPC technologies and their private sector use. "What is happening today is that the gap is widening between the known potential of high performance computers and the capability that is actually being realized with commercial off the shelf hardware and associated software," he said.

He noted that the government's science role clearly extends to economic security. "We do feel responsible for the economic security of the nation," said Dr. Marburger. "And we believe that our economic future depends on being able to continually innovate, and we know that innovation depends on science. Therefore we think it's important to invest in science and to try and understand the whole chain of investment that leads from that investment, whether in HPC or physics, all the way to making products and selling them competitively. We want to make sure that this process works for the American people."

An HPC Vendor Perspective: The Power to Transform the Business Enterprise System

HPC is clearly critical not only to America's strategic strength but also its economic might, Dr. Paul Horn, IBM's Senior Vice President for Research, told attendees during the conference's morning keynote address. He stressed that HPC is a crucial 21st century commercial innovation tool.

"The economy in the U.S. is the biggest not because we have the most productive workers, but because we dig holes with backhoes not shovels," said Dr. Horn. He provided a myriad of examples in which HPC is central to the success of companies in sectors such as petroleum exploration and production, aerospace, life sciences, entertainment and financial services.

Dr. Horn pointed out that the conference's focus on HPC and competitiveness is a timely one that is the result of a variety of converging global forces. These include the commoditization of HPC technology, the globalization of business competition, and the recognition of the enormous potential of HPC to transform business practices, as it has scientific ones. "HPC has become the third leg of science," noted Dr. Horn. Along with experimentation and theorizing, scientists and engineers can now use high performance computing to make discoveries in simulations of real-world events. There's now in vivo, in vitro, and in silica. HPC simulations are dramatically accelerating the rate of discovery in fields from astrophysics to material science.

Dr. Horn identified three key current trends in business HPC use that reflect its growing competitive importance:

- *Computational needs of businesses continue to grow rapidly,* such as in moving to the use of full model simulations and computer-generated movies with ever more life-like images.

- *There are enormous opportunities for further productivity gains with HPC.* Companies can extract trillions of dollars in excess cost through business enterprise transformation. According to Dr. Horn, this opportunity is particularly present, and untapped, in the services sector. This sector accounts for 80 percent of the U.S. economy, but is a late-comer in the use of HPC. He stressed that HPC can be used to redesign the fundamental business operations and processes within companies. This includes using HPC to model business optimization, such as real-time technical and business integration from raw resource to finished product.

- *There is enormous potential for ongoing application of HPC to many scientific fields such as drug discovery.* "We're at the infancy of a revolution in drug discovery and this won't happen without HPC," said Dr. Horn.

HPC Drives Business Competitiveness

HPC clearly provides substantial benefits to America's scientific and national security community. But how does this translate into business economic competitiveness? In the view of Dr. James F. Decker, Principal Deputy Director, Office of Science, DOE, and the moderator of the conference's first panel, in today's intensely competitive global marketplace it's a question that warrants particular attention in thinking about the national value of HPC.

"At one time the U.S. held an unchallenged leadership position in both the development and application of supercomputers," noted Dr. Decker. "However, today other countries have aggressive governmental HPC programs that represent significant challenges to U.S. leadership in both government research programs and industry."

Dr. Decker moderated a panel of four senior HPC industry users representing the broad spectrum of aerospace, consumer products and entertainment users. What, he asked them, are the current competitive advantages of HPC to their industries? How could the intractable industrial challenges they face be aided by increased HPC power? And what impact would this have on their companies' competitiveness?

Reducing Design Costs Through Virtual Prototyping

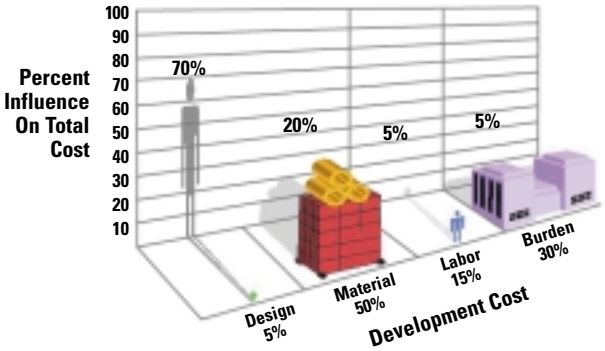
It costs approximately one billion dollars in R&D to design and test an aircraft engine, Pratt & Whitney Senior Fellow Dr. Saadat Syed told the conference. He explained that these turbines are very complex, multicomponent systems that require extensive design and analysis testing. However, the opportunity exists to wrench costs from old-line testing through the use of high performance computing. Virtual prototyping is essential to minimizing these costs, he said.

"Physical testing is very expensive and takes a lot of time," Dr. Syed told attendees. "We use HPC to analyze these designs before we take them to physical testing. This is where HPC can have a huge impact."

This virtual prototyping has a disproportionately large, positive, competitive impact on the engine's total cost compared with other R&D investments, noted Dr. Syed. While product design traditionally accounts for about five percent of the development costs, its influence on the final product costs can be as high as 70 percent. And, he emphasized that improved computing capability will lead to better designs and reduced R&D costs.

Reducing Physical Tests for Faster Time to Market

Design & Analysis Tools Have a Large Influence on Total Product Cost



Courtesy of Pratt & Whitney.

Reinforcing Dr. Syed's comments, Doug Ball, Senior Manager, Enabling Technology and Research at The Boeing Company, provided a powerful example of how HPC simulations are drastically reducing the need for costly physical testing, and also reducing the critical issue of time to market.

The Boeing Company has reduced the number of expensive and time-consuming wind tunnel tests for the wings of its new planes by using HPC-based computational fluid dynamics simulations. In 1980, Boeing conducted 77 wind tunnel tests during the development of its 757 wings. For its 7E7 Dreamliner series currently in development, Ball estimates it will require as few as five wind tunnel tests. "If you can take five months out of the design time it's a lot cheaper," noted Ball. "And the competitive advantage of HPC comes from being the first to apply these insights in the market."

According to Ball, not only do the simulations reduce development costs and time to market, but they produce a better product. He pointed out that since air is invisible it's impossible to visualize the air fluid dynamics around an aircraft's wings in a wind tunnel. However, this can be done using simulations, thus providing more detailed and useful results.

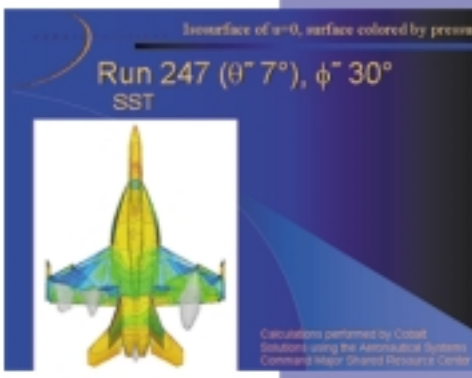


Image courtesy of The Boeing Company.

Breakthrough Insights for Manufacturers

While the aerospace industry, starting in the 1970's, was the first business sector to use HPC it has progressively moved into other sectors, including automotive, petroleum, entertainment, pharmaceutical, and notably, consumer products and packaging, observed Thomas J. Lange, Associate Director, Corporate Engineering, Head of Computer Assisted Engineering at The Procter & Gamble Company.

He pointed out that it might come as a surprise that the company that makes such well-known consumer brands as Pampers®, Tide® and Scope® spends $1.6 billion annually on R&D and has more than 24,000 active patents. And, he stressed, today HPC simulations are central to all of his company's R&D. "Explore digitally, confirm physically," is now the mantra at The Procter & Gamble Company, says Lange.

The use of HPC simulations extends from such large scale issues as modeling supply chain throughput reliability, to the virtual testing of bleach containers for their resistance to breaking when dropped, an important cost issue that involves maximizing container shape and safety while minimizing packaging costs. High performance computing also offers the promise to revolutionize manufacturing through advanced modeling and simulation of the entire process from concept through production, linking product development and manufacturing into a seamless process.

Lange told attendees that advanced simulations are also used to solve seemingly simple production questions. He explained how computational scientists at The Procter & Gamble Company turned to high performance computers and computational fluid dynamics equations similar to those used to analyze aircraft wings to solve the problem of the "flying Pringles®." The company's Pringles potato chips were literally flying off the conveyor belt rather than dropping into their tubular container because of irregular airflow around the uniquely designed snack food. The result was increased costs from contaminated product that had to be thrown away, not to mention a significant cleanup problem. Company scientists were able to model the air turbulence around the Pringles and adjust the manufacturing process accordingly to accommodate for this.

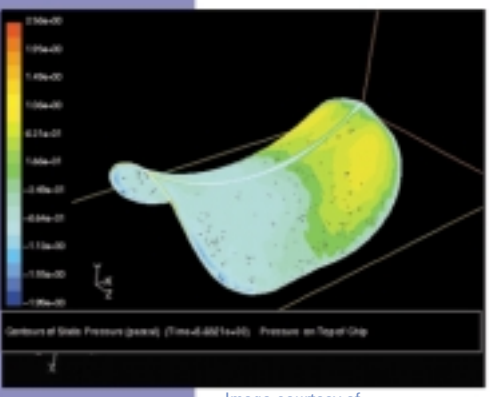


Image courtesy of
The Procter & Gamble Company.

HPC Creating New Industries

Ed Leonard, Chief Technology Officer at DreamWorks SKG, extended the application of HPC to note that the technology has created a whole new digital animation industry, which is drawing audiences around the world, and profits for the U.S. entertainment sector.

Leonard explained to attendees that the company's recent film ***Shrek 2*** would have been impossible to create without advanced HPC resources—each of the film's 130,000 frames required 80 hours of processor time, a total of a remarkable 10 million CPU hours to create a 90-minute digitally rendered film.

He explained that HPC enables filmmakers to produce computer-generated characters that behave, and more importantly for viewers, appear, like the real thing. ***Shrek 2*** wowed audiences in large part because a range of HPC hardware and software tools enabled filmmakers to control subtle aspects of lighting to characters' fur and clothing texture, creating a form of stylized realism. "People know what cloth looks like and how it should move, and if it doesn't they notice," said Leonard. "We couldn't do this without high performance computing."

Winning Globally Requires HPC-Driven Solutions

Given the level of global competition, use of high performance computing is no longer an option. It is an essential tool for developing and commercializing the next generation of high value products and services for which global consumers will pay a premium and that will capture global market share. Market leaders are and will be those that harness this capability to its full advantage.

All of the panelists emphasized that their companies need improved HPC resources to help solve a range of currently intractable, major R&D problems in order to meet growing international competition.

"My vision is to take an engine to verification testing without doing physical engine testing. Some people laugh at the idea," said Pratt & Whitney's Dr. Syed. However, he was far from alone among the panel's HPC leaders in seeing the possibility for dramatic HPC-driven competitiveness advances.

"We've pretty much reached the limits of what planes are going to look like. They're no longer just going to be tubes with wings," said The Boeing Company's Doug Ball. He noted that in order to achieve this conceptual leap, the 21st century HPC challenge is to dramatically reduce the time required for HPC simulations, and thus the testing of various iterations of new models.

It's this type of leap to the next level of HPC innovation that panelists said will provide American businesses with a significant, international competitive advantage.

Ball pointed out that the international commercial aircraft market for the next 20 years is estimated at about one trillion dollars. However, there's intense competition for this market. Dr. Syed noted that the European Union has committed billions of euros of public funding to achieve "a world-class European aeronautics industry (that) leads in global markets for aircraft, engines, and equipment by 2020." Already Pratt & Whitney's market share has declined 10 percent vis-a-vis European competitors since 1992.

Ed Leonard, of DreamWorks SKG, noted that global competition is also a key factor in the digital film industry with emerging competition from countries such as India and China. In Leonard's view, to meet this competition, "We need better development tools to make HPC computing faster, easier, and more reliable." For example, in order to develop several films simultaneously and thus have a richer product pipeline, he said DreamWorks requires better cluster-management software that provides intelligent real-time configuration and prioritization of processors.

Similarly, The Proctor & Gamble Company's Lange noted there are whole realms of product design R&D possibility still untapped because of the need for HPC simulations with greater detail and integration ability.

His vision for future virtual design includes the ability to simulate a person's biomechanical interaction with a product, such as removing the top of a plastic container. It's an advance that would greatly accelerate the design analysis process, and thus time to market. However, Lange noted, to make this a reality will require the development of complete biomechanical simulations that mimic muscle, fat, skeletal and skin behavior that can interact with simulated products.

First National HPC Users Survey: Essential Tool Needs Broader Usage

The critical link between HPC and business competitiveness identified by the conference's first panel was reinforced by the results of the first High Performance Computing Users Survey. It was released at the conference by the survey's leader, Dr. Earl Joseph, Research Vice President, High Performance Systems Program, International Data Corporation.

The survey—an initiative of the Council on Competitiveness and DARPA—was commissioned to provide a detailed, birds-eye view of HPC business use in America. Why do American companies acquire HPC resources? How are they using them? What is HPC's impact on their competitiveness? And what's the industry's outlook for future HPC use, including the potential value of high performance computers that are dramatically faster and easier to use?

The survey's respondents were veteran chief technology officers, chief information officers and production and research managers from companies representing the full range of industries using HPC today, including IT and electronics, petroleum, chemical, pharmaceutical, aerospace, automotive and entertainment. These companies' experience with HPC ranged from two to thirty years, with an average of 15 years.

The survey's core finding? HPC is an indispensable business tool to dozens of America's largest companies, but this powerful innovation driver is not used as aggressively as possible because of a variety of technical, cost and business culture hurdles.

Dr. Joseph highlighted the major findings to conference attendees:

- ***High Performance Computing Is Essential To Business Survival***

Respondents were near unanimous in indicating that HPC is so central to their work that their organizations couldn't function without it. The number-one reason given for purchasing HPCs is their unique ability to run very large and complex computational problems that these companies must successfully address to maintain competitive advantage.

- ***Companies Are Realizing A Range Of Impressive Bottom Line And Business Benefits From Using HPC***

The competitive benefits of HPC use identified included shortened product development cycles and faster time to market—in some cases more than 50 percent faster—and an associated reduction in R&D and production costs.

- ***Dramatically More Powerful And Easier To Use Computers Would Deliver Strategic Competitive Benefits And Could Add Billions To A Company's Bottom Line***

Those respondents who were able to quantify the potential benefits from access to more powerful and easier-to-use

HPC systems suggested bottom-line benefits of from tens-of-millions to billions of dollars. Given the possibility of HPC systems 100 times faster and ten times easier-to-use, respondents' projections included the comments that: "We could save $1 billion from a faster cycle time," "We could test two-generations-out models that we are researching today," and "We would look to rewrite the entire science underlying the current technology and methodology we are using."

- ***Companies Are Failing To Use HPC As Aggressively As Possible***

A majority of respondents indicated that they are not using HPC as aggressively as possible. In some cases this is due to a variety of business and technical barriers. In others, the HPC resources simply don't exist today to solve the specific problems.

- ***Business And Technical Barriers Are Inhibiting The Use Of Supercomputing***

"The largest single factor preventing more aggressive use of HPC tools is the lack of computational scientists either within a company or externally who are able to apply HPC tools to the company's problems," Dr. Joseph told attendees. A closely related issue is the current difficulty of use of both hardware and software that limits the broader application of HPC in many businesses.

The survey also found that despite proven returns on investment, "respondents noted that upper management often does not appreciate the value of HPC hardware, software and tools. As a result, HPC is often viewed as a cost instead of an investment, and many sites find it difficult to acquire internal funding to acquire HPC resources."

- ***Companies Don't Have The HPC Tools They Want And Need***

A majority of the executives interviewed said that there are existing HPC tools that they would like to own or access but don't because of a number of financial and business culture reasons. However, a third said that they need hardware or software systems more powerful or capable than any available on the market today.

Key Conclusions: HPC by the Numbers

Here are some highlights, by the numbers:

- *Percentage of industrial and business users surveyed for whom HPC tools are indispensable:* **97**
- *Percentage of users surveyed for whom HPC tools shorten product development time and enable them to tackle more and larger problems:* **70**
- *Percentage who say they can't afford to purchase the HPC tools they'd like:* **67**
- *Percentage with major important technical and/or scientific problems that require more advanced HPC tools:* **67**
- *Percentage who said they didn't think their business was using HPC as aggressively as possible:* **58**
- *Percentage for whom improved ease-of-use would increase their company's use of HPC:* **56**

Not all respondents answered every question.
To read the full National HPC Users Survey visit www.compete.org.

Barriers to HPC Use in Industry

The barriers to the use of HPC by American businesses uncovered by the National HPC Users Survey, were reiterated and further elaborated on by the afternoon panel moderated by Dr. David B. Nelson, Director, White House National Coordination Office for Information Technology Research and Development.

The four leadership panelists represented a diverse range of fields, from industrial to engineering and the financial and banking services to academia. When introducing the panel, Dr. Nelson summarized the barriers they would be addressing into three broad categories:

- *Business culture barriers*
- *Educational/training barriers*
- *Technical barriers*

But he also encouraged all conference participants to focus on not only the barriers, but also ways to overcome them. "This conference is in a sense a problem solving and an opportunity realizing event," observed Dr. Nelson. "Barriers can be easy ways to say 'no.' But we should find ways to say 'yes'."

Business Culture Barriers

Panelists identified two overarching business culture barriers that face those promoting greater HPC use in their companies: the question of whether HPC is viewed as an investment or cost, and the related issue of identifying return-on-investment.

• *HPC: Investment or cost?*

In the boardrooms of many American companies, HPC isn't seen as an innovation edge, but rather a cost of doing business that's viewed as "an enormous hole in the pocket book," said Daniel Wolgemuth, Senior Vice President/Chief Information Officer HNTB LTD. This company is one of America's top 20 design engineering firms and uses HPC in the design and analysis of large tunnels, bridges and stadiums.

His comments echoed the findings of the HPC Users Survey which noted that for many companies, especially those with less experience using HPC to solve their business problems, senior executives view these resources as a cost rather than an investment. According to Wolgemuth, this attitude represents a major mindset hurdle that must be addressed if we are to realize increased use of HPC to boost competitiveness.

Indeed, he said, for many companies taking advantage of HPC means rethinking the integration of HPC into their business and profit models. For example, the current project pricing models used in many consulting companies are time-based. As such, there's reluctance on the part of some team members to rapidly accelerate the design and delivery process with HPC.

"In the consulting world, faster isn't always [seen internally as] better," noted Wolgemuth. "So in the professional services marketplace, if we're going to really innovate we have to come up with new HPC-related pricing models that are value based."

• *The return-on-investment factor*

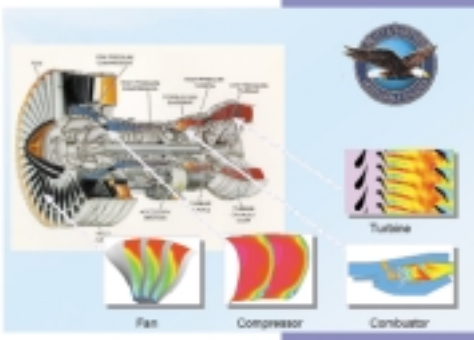


Image courtesy of Pratt & Whitney.

Part of the reason that senior executives view HPC as a cost rather than an investment is that, in most cases, they're not given a quantifiable sense of their return on millions of dollars of investment in HPC infrastructure and staffing, said Jeffrey Birnbaum, Managing Director, Global Head of Enterprise Computing, for Morgan Stanley.

"Return on investment is one of the big issues if we're going to make this (accelerated vision of HPC) a reality," he noted. Morgan Stanley uses HPC extensively for market analysis and modeling for derivatives and other trading.

In Birnbaum's view, what he terms "legacy thinking"—a psychological tie to doing things in a traditional way—can be a major hurdle to using the latest HPC resources for competitive business advantage. He noted that this is a particularly important issue given that America's major emerging competitors—India and China—don't have the same, potentially stunting, legacy of HPC use, or nonuse.

Missing the Right Stuff: Educational and Training Barriers

Today, many industries don't have the people who can productively use HPC to its full innovation potential, said Dr. Stan Ahalt, Executive Director of the Ohio Supercomputer Center.

In Dr. Ahalt's view part of the reason for this is that educators need to emphasize greater vision and imagination when it comes to applying HPC to real-world problems—they need to encourage students to think big. "We don't teach our students to think about what problems they could

solve if they had an infinite amount of computational time and an infinite amount of storage," said Dr. Ahalt, noting that these students will have access to much larger HPC systems than available today.

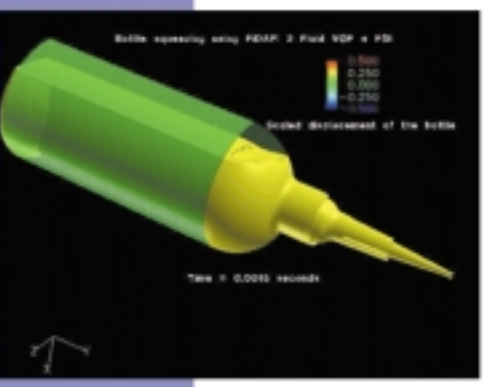


Image courtesy of The Procter & Gamble Company.

The panelists identified a two-pronged shortfall in human resources for HPC use in businesses, (though there was a range of opinion over the extent of the problem):

- *Not enough people in the HPC educational/training pipeline;*
- *A poor match between the education provided by universities and the particular HPC skills and multidisciplinary perspective required by industry.*

"Today's engineering undergraduates are rarely taught passé programming languages and there's no introduction to distributed parallel programming. As a result, graduate student programming skills are poor," said Dr. John O. Hallquist, president of Livermore Software Technology Corporation, a leader in the development of the simulation software used in automobile crash modeling.

According to Dr. Ahalt, the result of this lack of parallel programming skills in industry "is that engineers settle on sub-optimal designs."

It's a vicious circle in which an unclear sense of the value of human resources reduces the real value of HPC ownership and use, and thus exacerbates the perception of HPC hardware and software as a cost rather than an investment, noted Morgan Stanley's Jeffrey Birnbaum.

HPC Technical Barriers

The panelists identified key technical barriers that fall into three broad categories:

- ***Need for improved mathematical models and basic science***

Dr. Hallquist noted that mathematical models are the foundation for all high performance computing since they convert scientific insights about physical processes into a form that can be used for the development of computer codes and software.

He identified a range of modeling issues which are currently barriers to more advanced simulations using his company's finite element software. These include load balancing in parallel computers (the ability to share the workload efficiently among hundreds, or thousands, of processors), and the level of accuracy of highly complex, multicomponent physics models such as automobile crash simulations.

"We need to be able to run a model twice and get exactly the same answer. The ultimate goal is to reduce the number of physical prototypes to zero," he said.

- ***Legacy software inhibiting usage***

American businesses are relying on a diverse range of proprietary in-house and commercially available outsourced software to meet their HPC needs. Legacy codes, especially third party software legacy codes, are seen by some as a significant obstacle to more widespread use. Many important HPC application codes have been in use for decades. But whichever route they're taking, a major barrier for all is the applicability, compatibility and ease-of-use of their HPC software.

"It's HPC software that needs dramatic improvement," said Dr. Ahalt. "So if we can solve the basic problem of better applied parallel software, the entire spectrum of HPC applications from basic science to industry will reap the benefits."

He added that the HPC software crunch extends beyond the technical applications to issues of HPC load balancing, optimization, cluster management and advanced visualization.

- ***The right fit: Codes must be scaled for broader industrial use***

The emphasis in the government HPC community on the development of codes for parallel application on thousands of processors has created a barrier for many potential business users.

"To date the concentration in HPC has been on high-level, sophisticated programs rather than simpler, more broadly applicable applications," said Dr. Ahalt. He notes that while the codes developed by DoD, NSF and DOE often involve thousands of processors, most industrial applications involve less than 64 processors. "Right scaling" the codes, he suggested, is thus a significant and sometimes insurmountable obstacle for industrial HPC users.

What Drives Business HPC Decisions?

During the course of the conference, panelists and speakers identified four key business issues, which, although not "barriers," form the framework within which American businesses are making decisions about HPC purchase and use.

Cost is Core

Cost issues are the driving force in the business use of HPC. "I can't tell you the number of times people feel constrained because of the costs of HPC," noted Jeffrey Birnbaum of Morgan Stanley.

Questions of cost apply not only to the hardware, but also to the software, and to facilities issues such as HPC housing and cooling, noted The Boeing Company's Doug Ball. Indeed, he said, for some users the cost of simulation software dwarfs the cost of the hardware. In this sense, cost is a critical issue in limiting the transition from physical testing to the use of advanced simulation.

According to IBM's Dr. Horn cost is an issue that's recognized by HPC suppliers. "We need to build the technology at a low enough cost to allow our customers to use it."

Productivity, not Speed

The traditional HPC metric for measuring performance is raw processor speed. Supercomputers on the Top 500 Supercomputer List are ranked based on flops, the number of floating point operations per second. "We've got to find a better way of defining performance other than flops," said one conference attendee voicing a commonly held sentiment. For business users the key performance metrics are HPC price, suitability to their specific applications, and the speed at which the machine can run their specific applications. Indeed, in many cases, application specificity and experience with a particular hardware architecture are more important than cost or potential speed using a new hardware platform.

HPC is a Tool

"The key thing for our engineers is using the HPC as a tool—they don't care about computational fluid dynamics," said The Boeing Company's Ball. Easier to use systems not only benefit experienced HPC users, but also invite a larger pool of individuals to use this tool, ultimately expanding potential applications, noted Dr. Ahalt.

Choices, not Answers

HPC users emphasized that in a business setting HPC doesn't provide singular solutions, but rather additional critical information on which to base business decisions.

"There's always someone who knows the answer. The challenge is to get the other 10,000 people to agree. The benefit of modeling is in helping to get people to agree. It aids executives' intuitive decision making," said Procter & Gamble's Thomas Lange.

Next Steps: Supercharging U.S. Innovation with HPC

"What is our vision for the future? What are the next steps?" asked Dr. Holbrook, President, The Ohio State University and CoChairman, Council on Competitiveness HPC Advisory Committee, in leading the conference's closing discussion on the next steps.

In providing a context for this discussion, she noted that in her view "What we've heard is that there's very clear agreement on the transformational capabilities of HPC and our ability to innovate to give our businesses, our scientists and engineers, and our nation a competitive advantage to enhance productivity and national security."

Participant suggestions for overcoming hurdles to HPC use and capitalizing on its potential to fuel U.S. economic competitiveness fell into five broad categories:

Strengthening Government, Industry, University Partnerships

Panelists, speakers and attendees emphasized that the main priority is the need for renewed and reinvigorated partnerships between businesses, government, and academia. What shape should such partnerships take in the 21st century?

As the DOE's Dr. Decker stated, "I think one of the important issues in advancing HPC in this country is how do we improve the connections between government and industry to help facilitate development in both sectors." These partnerships include the need to reinforce, re-establish, or create links and government-industry partnerships between software and hardware development to avoid the "not-invented-here syndrome" in many businesses, said The Boeing Company's Doug Ball.

In terms of interagency linkages within the federal government, Dr. Marburger, Science Advisor to the President and Director of the Office of Science and Technology Policy noted that High End Computing (HEC) is one of six major areas within the Networking and Information Technology R&D (NITRD) group, one of the President's major interagency coordination efforts funded at more than $2 billion annually. He noted that NITRD has formed a High End Computing Revitalization Task Force which produced a report, released in May 2004, outlining among other things an interagency roadmap for high-end computing core technologies and an accessibility improvement plan.

Improving HPC Education and Training

While views differed as to the extent of the problem, there was a widely shared perspective that there's need for improved linkage between the HPC skills and knowledge taught by universities and those required by private sector companies. At the same time, companies must maintain adequate internal human resources to maintain HPC innovation. "There's no way around spending money on people," said Dr. Beckner of DOE's National Nuclear Security Administration.

Conference participants also noted the need to emphasize multidisciplinary training and an increased understanding of parallel programming methods. This multidisciplinary training includes not only the ability to understand the scientific and technical aspects of a problem, but also how to work collaboratively with a diverse range of partners for whom HPC is a "black box" that purely provides a service on the way to a product. "Even with our most technical folks there needs to be the ability to communicate with the artistic folks," said Ed Leonard of DreamWorks SKG.

Fueling Next Generation HPC Simulations

The ongoing and targeted role of university and government agency research in developing ever more advanced mathematical models and codes is crucial to making the leap to a next level of innovative HPC use by American businesses. "It's not the lack of sheer crunching power, it's the lack of ability. We need the math and models or all the computer cycles won't help," said one attendee during the general discussion on solutions.

Participants felt it's critical that government and academia continue to play a leadership role in advancing HPC applications, demonstrating proof-of-concept, and efficiently sharing these advances with industry. "It's very important for government agencies to demonstrate that whole system simulations can be done," noted Dr. Syed of Pratt & Whitney.

This new science and engineering insight extends to the entirety of the HPC envelope, including faster, more reliable networking, scalable parallel algorithms and the need for ever greater fidelity of models. The issue of model validation is crucial to the regulatory approval of HPC models as an alternative to physical testing.

Imaging New Business and Value Models

Businesses must change the ways they think about HPC in their value models. And this change in thinking must be championed internally by HPC users and clearly communicated through "upreach" to the boardroom level. "As HPC leaders, it's our job to translate the HPC dream into something that works in the boardrooms across the United States. Can it be done? Absolutely, " asserted HNTB LTD's Daniel Wolgemuth.

Next Generation Access Scenarios for Business HPC

There were three proposed scenarios for increasing HPC use, each briefly outlined here:

• *Computing on demand*

Also described as "utility computing," this scenario envisions a new market model. Rather than maintaining costly, permanent internal resources, businesses such as digital animation companies would be able to access HPC resources on an "as needed" basis, primarily to meet peak demand. However, some conference participants thought this model could involve seemingly prohibitive security concerns for many companies.

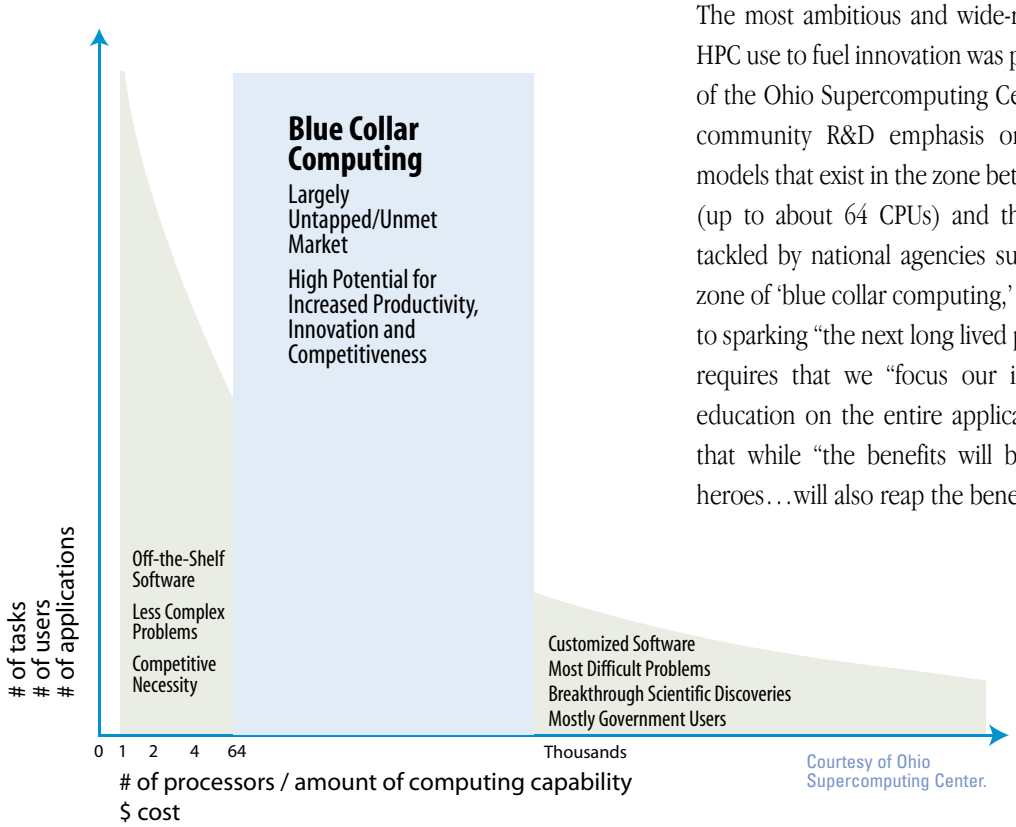
Image courtesy of DreamWorks SKG.

• *Competitive computing*

As with computing on demand, this scenario also sees a broadening of competitive HPC use by lowering the cost of computing through maximizing the use of internal computing resources. This involves operating HPC resources in what Morgan Stanley's Jeffrey Birnbaum termed a "stateless compute environment," in which HPC assets act as a large dynamic pool available to a broad range of users, including the potential to sell cycles to recoup investment. This relies on the development of easy-to-use software that can be broadly applied.

• *Blue collar computing*

The most ambitious and wide-ranging vision of change in HPC use to fuel innovation was presented by Dr. Stan Ahalt, of the Ohio Supercomputing Center. He proposed an HPC community R&D emphasis on improved programming models that exist in the zone between dominant current use (up to about 64 CPUs) and the "heroic" scale problems tackled by national agencies such as DOE and DoD. This zone of 'blue collar computing,' he said, offers a logical step to sparking "the next long lived productivity expansion" and requires that we "focus our innovations, advances, and education on the entire application spectrum." He added that while "the benefits will be primarily economic, the heroes…will also reap the benefits."



Courtesy of Ohio Supercomputing Center.

Looking to the Future

Based on the results of the 1st Annual High Performance Computing Users Conference, the Council on Competitiveness' HPC Advisory Committee has the clear direction to identify opportunities for public-private partnerships, said cochair Dr. David Shaw. This is now at the heart of the Advisory Committee's work in creating an Action Agenda. And it will form a key part of discussions at the 2nd High Performance Computing Users Conference, planned for July 13, 2005.

In closing, Advisory Committee cochair Dr. Karen Holbrook reiterated a statement by Dr. Marburger made during his keynote address that she believed encapsulated the day's events: "We are approaching a 'tipping point' beyond which entirely new applications of computing will bring a new wave of transformations in our industrial ways of life, and further disrupt older ways of doing business," said Dr. Marburger. "We need to spread the word about the new capabilities and build confidence in the new visions to motivate private and public investment in them…. In today's globally competitive economy we cannot afford to leave this to others."

Appendix

Conference Agenda

Executive Summary of HPC Users Survey

Council on Competitiveness
High Performance Computing
Advisory Committee

Council on Competitiveness
Members, Affiliates, and Staff

FIRST ANNUAL
High Performance Computing Users Conference:
Supercharging U.S. Innovation & Competitiveness
July 13, 2004

AGENDA

7:30 a.m. Breakfast

8:15 a.m. **Welcome**

Deborah L. Wince-Smith, President, Council on Competitiveness

Dr. David E. Shaw, Chairman, D.E. Shaw & Co., Inc. and CoChair, Council on Competitiveness HPC Advisory Committee

Dr. Anthony Tether, Director, Defense Advanced Research Projects Agency

Morning Keynote Address: Competing through Computing Power: Leveraging HPC for Global Economic Leadership

Dr. Paul Horn, Senior Vice President for Research, IBM

Note that time is allocated within following sessions for questions and answers

9:15 a.m. **Panel 1: HPC: Key to Solving Industry's Intractable Problems**

Industry panelists will discuss cutting-edge business challenges that require more advanced computing capabilities, and the impact on competitiveness if these challenges can be successfully addressed.

Moderator: Dr. James F. Decker, Principal Deputy Director, Office of Science, Department of Energy

Doug Ball, Manager of Enabling Technology and Research, The Boeing Company

Thomas J. Lange, Associate Director, Corporate Engineering, Head of CAE, The Procter & Gamble Company

Ed Leonard, Chief Technology Officer, DreamWorks SKG

Saadat Syed, Senior Fellow, Pratt & Whitney

10:45 a.m. **Break**

11:00 a.m. **HPC User Trends: Results of the First National High Performance Computing Users Survey**

Survey results will be released, revealing trends in why companies acquire HPC, how they are using HPC, the impact on their competitiveness, and industry's outlook for future use.

Dr. Earl Joseph, Research Vice President, High Performance Systems Program, International Data Corporation

12:00 p.m. Dr. Everet H. Beckner, Deputy Administrator for Defense Programs, National Nuclear Security Administration, U. S. Department of Energy

12:15 p.m. **Luncheon**

Luncheon Address: Global Challenges: HPC Solutions

Why leadership in HPC is important to achieving both U.S. national security and economic competitiveness goals.

John H. Marburger III, Science Advisor to the President and Director of the Office of Science and Technology Policy

2:00 p.m. **Panel 2: Barriers to Industry HPC Usage**

Industry and university panelists will discuss barriers that companies face in acquiring and applying HPC to solve industry challenges and ways they are successfully addressing them, if in fact they are.

Moderator: Dr. David B. Nelson, Director, White House National Coordination Office (NCO) for Information Technology Research and Development (IT R&D)

Dr. Stan Ahalt, Executive Director, Ohio Supercomputer Center

Jeffrey Birnbaum, Managing Director, Global Head of Enterprise Computing, Morgan Stanley

Dr. John O. Hallquist, Founder and President, Livermore Software Technology Corporation

Daniel Wolgemuth, Senior Vice President/Chief Information Officer, HNTB LTD.

3:30 p.m. **Next Steps/Comments from Attendees**

Dr. Karen A. Holbrook, President, The Ohio State University, CoChairman, Council on Competitiveness HPC Advisory Committee

4:00 p.m. **Adjourn**

EXECUTIVE SUMMARY

Commissioned by the Council on Competitiveness from IDC,
and sponsored by the Defense Advanced Research Projects Agency

Executive Summary

This study, commissioned by the Council on Competitiveness (COC) from IDC, and sponsored by the Defense Advanced Research Projects Agency, explores the usage and impact of high-performance computing (HPC) resources in industry and other business sectors — including currently available HPC computers and potential future computers assumed to be dramatically faster and easier to use. The study asked about both capacity-class computers, purchased primarily to address many small and medium-sized problems, and capability-class computers, purchased mainly to tackle the largest, most daunting individual problems. The 33 participants in this study are seasoned private-sector chief technology officers (CTOs), chief information officers (CIOs), and production and research managers representing a wide range of business segments that employ HPC today — from leading aerospace, automotive, petroleum, electronics, pharmaceutical, life sciences, and software companies to financial services, transportation logistics, and entertainment firms. Complete survey results are available on the Council on Competitiveness web site *www.compete.org*.

Major Findings

High-Performance Computing Is Essential to Business Survival

Nearly 100% of the respondents indicated HPC tools are indispensable

High-performance computing is not only a key tool to increasing competitiveness, it is also a tool that is essential to business survival. Nearly 100% of the respondents indicated that HPC tools are indispensable, stating that they would not exist as a viable business without them or that they simply could not compete effectively. A majority (70%) of the respondents indicated that HPC is so important that their organizations could not function without it.

Risks from Not Having Access to HPC Computers

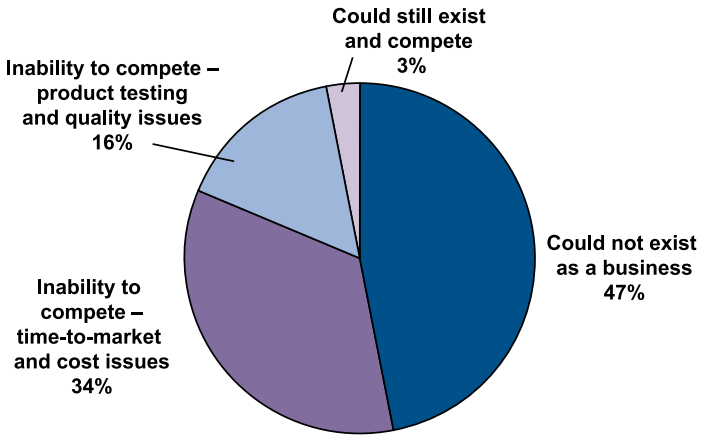


Figure 6 *Source: IDC, 2004*

"There is no other way for us to complete our work. We would not exist."

Typical comments include:

"There is no other way for us to complete our work. We would not exist."
"The time to market would prohibit our business from existing."
"We would not be able to stay technologically ahead of other competing nations."

The number 1 reason given for purchasing high-end computers is their unique ability to run very large and very complex computational problems that companies must successfully address to maintain their competitive advantage. In addition to running these large-scale problems, the majority of respondents are also able to harness the computer power to run a larger number of smaller-scale, important problems than they were able to run in the past.

Companies Are Realizing a Range of Financial and Business Benefits from Using HPC

"It drives innovation, R&D effectiveness, and productivity."

Companies described a range of impressive competitiveness benefits realized from using high-performance computing. Approximately one-quarter of the respondents were able to quantify the ROI to their organizations, in some cases in the millions of dollars. Strategic competitive benefits included gains such as shortened product development cycles and faster time to market (in some cases more than 50% faster), not to mention the resultant reduced costs, all of which can improve a company's bottom line.

"It has been a continuous stream of revenue to our bottom line, giving us the ability to look into other development areas."

"It drives innovation, R&D effectiveness, and productivity."

Companies Are Failing to Use HPC as Aggressively as Possible

Despite the acknowledged importance of high-performance computing to business competitiveness, a majority of respondents acknowledged that they are not using HPC as aggressively as possible. Two-thirds of the respondents indicated that they have important problems that they simply can't solve today. The remaining third said that they need more powerful systems to achieve more effective solutions. Reasons for both vary. In some cases, systems with the needed capability are on the market but companies face obstacles in owning or accessing them or in using them to their fullest capability. These barriers are discussed below. In other cases, the systems required simply don't exist.

Do Organizations Have Important Computational Problems They Can't Solve Today?

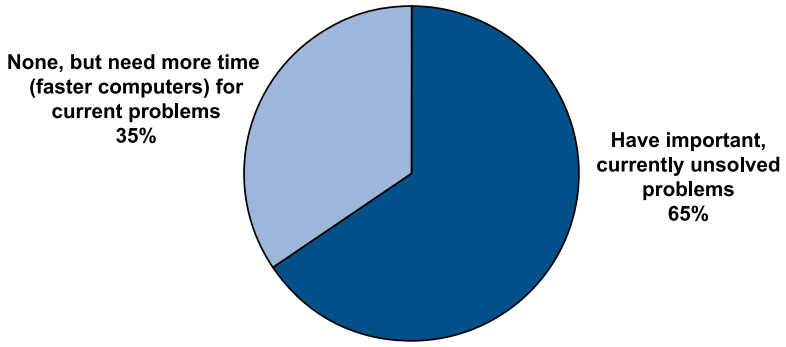


FIGURE 11 *Source: IDC, 2004*

Examples of current unsolved problems include modeling block engine assembly in full detail, simulating vehicle rollover, real-time processing of data from remote sensors, protein folding, and coordinating databases across tens of thousands of servers.

Business and Technical Barriers Are Inhibiting the Use of Supercomputing

Top Factors Holding Back Organizations from Using HPC Tools More Aggressively

- *Availability of internal or external people to apply the tools to our problems*
- *Ease of use (hardware and software)*
- *Easier to get decision on investment that reduces costs now versus future*
- *Cost of HPC tools (hardware, software) versus other business investments required*
- *Decision makers do not grasp HPC impact versus other business pressures*
- *Scalability of commercial ISV software*

TABLE 8 *Source: IDC, 2004*

The largest single factor preventing more aggressive use of HPC is the lack of computational scientists.

Respondents noted a range of reasons that HPC is not used more aggressively. The largest single factor is the lack of computational scientists — human experts (internal or external) who can apply HPC tools to the problems in question — and the budget to hire them. In most cases, the concern was the lack of resources to hire people, but in a few cases, it was the lack of available talent in the marketplace. Closely related is the ease-of-use issue; most industrial sites require software compatibility in their HPC servers and the cost to change or rewrite software is frequently seen as prohibitive.

Despite the often proven returns from using high-performance computing, respondents noted that upper management often does not appreciate the value of HPC hardware and software tools. As a result, HPC is often viewed as a cost instead of an investment, and many sites find it difficult to obtain internal funding to acquire additional HPC resources. More than half of the respondents expect their budgets for all HPC tools will decline (43%) or remain the same (17%) over the next two years.

Companies Don't Have the HPC Tools They Want and Need

When asked if there are currently available HPC tools they would like to own or access, a majority of the respondents answered in the affirmative. Relatively even numbers of respondents pointed to currently available software and hardware tools they would like to own or access. However, 31.6% stated that there are either hardware or software tools missing in the market today, and 21% said that they need hardware systems that are more powerful than any available on the market today.

Most Companies Do Not Rely on Remote Access to HPC

When respondents were questioned about their methods of accessing HPC resources, most responded that they use on-site purchased or leased HPC systems instead of accessing them remotely at partner or external provider sites. And most do not expect to outsource their most complex (and therefore most competitively sensitive) problems in the future. Security is an important inhibiting factor for some companies.

Dramatically More Powerful and Easier-to-Use-Computers Would Deliver Strategic, Competitive Benefits

"It would make these tools available to a much wider array of scientists who have good ideas but may not have programming skills."

When respondents were asked what they could accomplish with systems 100 times more powerful and/or 10 times easier to use, their replies again reflected the strategic importance of HPC to competitiveness. They saw opportunities to simulate larger, more accurate models and tackle completely new problems that they cannot address today, resulting in the ability to produce higher quality products, achieve faster time to market, and improve their financial performance.

When asked what could be accomplished if the "ease-of-use" barrier were addressed with systems that are 10 times easier to program, respondents overwhelmingly indicated that they could develop more powerful applications and fundamentally rewrite their current codes.

Not surprisingly, they also indicated that they could shorten design cycles and time to market, a natural by-product of better applications. In addition, more easily programmable systems would enable a wider universe of researchers, scientists, inventors, designers, manufacturers, and mathematicians to use high-performance computing to solve their problems, extending the benefits of these systems more broadly across the private sector for increased industrial and national competitiveness.

"We could test two-generations-out models that we are researching today."

"It would increase revenues for the company and market share."

"We would look to rewrite the entire science underlying the current technology and methodology we are using."

"It would make these tools available to a much wider array of scientists who have good ideas but may not have programming skills."

"We save $1 billion from a faster product cycle."

Dramatically More Powerful and Easier-to-Use-Computers Could Add Billions to the Bottom Line

Although not all respondents were able to quantify the potential benefits from access to more powerful and easier-to-use systems, those who could suggested bottom-line improvements from tens of millions to billions of dollars, an enormous increase over the positive financial benefits users are already achieving today.

"We save $1 billion from a faster product cycle."

"I can't release [the amount], but it is in the billions a year."

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Executive Director
Pittsburgh Supercomputing Center

Greg Brandeau
Vice President of Technology
Pixar Animation Studios

Saadat Syed
Senior Fellow
Pratt & Whitney

Tom Lange
Chief Technologist for Reliability
Engineering
The Procter & Gamble Company

Mike Vildibill
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& Technical Computing
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