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WHITE PAPER

# Quad-Core Processors Bring Higher Performance and Lower Cost to Mainstream Computing

Sponsored by: Intel

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## EXECUTIVE SUMMARY

Intel's innovation in the x86-based server space brought the first quad-core processor to market in 4Q06. IT demand for these new products is high: Intel is on track to ship over 1 million quad-core processors in the first half of 2007, and as of March 2007, nearly 1 in 5 new processors ordered from Intel are quad core. Intel's quad-core processors are designed to run in two-socket and one-socket systems.

This paper explores the market adoption of and customer value proposition and adoption plans for the Quad-Core Intel Xeon processor 5300 series since its market introduction in 2006, focusing on workloads that are designed to run on multicore and multisocket platforms. In addition to discussing the range of workloads, IDC has interviewed customers who are adopting the Quad-Core Intel Xeon processor 5300 series to learn about the IT requirements that they are addressing and the deployment patterns found in those sites.

## INTRODUCTION

Quad-core technology uses four separate logical processing units on a single processor that shares memory, I/O, and caching. The result is a processor that consumes as much power as, or less power than, a single- or dual-core processor, yet provides significantly more processing performance than a single-core or dual-core processor. Because the power consumption per core is reduced, performance per watt is increased. Users can dedicate individual cores to different applications, providing a natural platform for consolidation. The processor can simultaneously handle multiple threads that can help reduce latency when more than one thread per application or more than one application is running. Although servers are the focus of this paper, quad-core technology is also proving valuable to two-socket technical workstations.

### How Quad-Core Technology Affects Customers

Servers using the Dual-Core Intel Xeon processor 5100 series are socket compatible with the Quad-Core Intel Xeon processor 5300 series. Although IDC does not believe many server users would upgrade only their processor instead of purchasing a new quad-core server, this upgrade could be done seamlessly and without disruption. Existing legacy software will also run on quad-core processors with no code changes or revisions retaining server certification.

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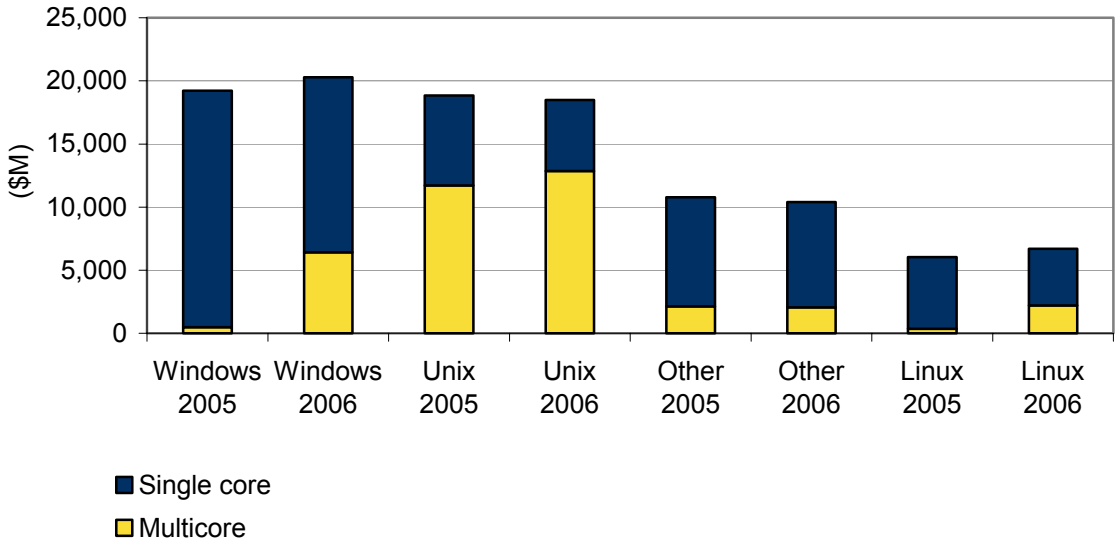
Quad-core technology provides a major performance increase over present single- and dual-core architectures and will be welcomed by server users. Quad core–based servers provide a new level of value for clients, delivering three to five times the performance of systems that were offered just 12 to 18 months ago. These new systems enable clients to significantly grow compute power by upgrading or replacing their current systems while maintaining the same hardware footprint or consolidating applications onto fewer, more powerful servers. Both solutions maximize control over energy spending and space utilization in the datacenter.

## Why Customers Should "Care" About Quad-Core Processors

Figure 1 illustrates the rapid growth of multicore processor–based systems revenue in 2006. x86-based systems were the primary driver of a 60% rise in systems revenue from 2005 to 2006. Windows-based systems grew more than 1,200% year over year (YoY), Linux grew 500% YoY, and Unix-based systems grew only 10% YoY. Multicore systems generated 42% of system revenue in 2006, up from 27% in 2005.

**FIGURE 1**

Worldwide Server Market: Customer Revenue by Processor Type and Operating System, 2005 and 2006




Source: IDC's Quarterly Server Tracker, 4Q06

The server market has seen a rapid transition from single-core to dual-core processors in the x86 server market. This platform change has been seen as the next step in server computing that offers the potential for more powerful and flexible computing. While the transition to dual-core processors is still occurring, Intel and its server OEM partners began shipping quad-core technology in November 2006. Because the change to quad-core technology is occurring so quickly, it will primarily replace an installed base of single core–based server systems. Thus, quad-core processors will provide a significant step up in compute capability, resulting in a three-time to five-time increase in power over single core–based systems at similar cost.

## SITUATION ANALYSIS

The enterprise datacenter currently faces multiple challenges as demand for new applications and improved availability drives a constantly increasing requirement for hardware resources. In the past, this demand has increased the installed base of servers within IT organizations and has led to escalating pressure on IT staff to maintain service levels as system management demands rise. For the past 12 to 18 months, many IT organizations have looked to emerging technologies to break this cycle, particularly as the spending for new IT projects increases along with the economic recovery in many regions.

**Virtualization.** Server virtualization has proven to be an effective technology for many customers seeking to increase hardware utilization levels and lower management overhead. These technologies are not new. The mainframe has been virtualized, or partitioned, for more than 30 years. Virtualization is new, however, to the x86 server market, and IDC has observed rapid rates of adoption. Between 2005 and 2010, we expect the number of new servers supporting virtualization to increase by more than three times. This carving up of a single physical server into logical server units enables customers to maximize available hardware resources, more rapidly deploy systems, and even improve their availability with the use of portability tools. This ability to more quickly respond to business change has many enterprise organizations seriously considering virtualization as a standard build for their infrastructure.

IDC believes virtualization will be a major factor in the decision to adopt quad core–based systems. Virtualization provides IT with an excellent tool for consolidating multiple applications on a single system to better utilize the expanded capability of these systems.

**Power.** Multicore-based system adoption has occurred over the same 12- to 18-month period. In addition to the desire to get better utilization of systems through virtualization, there has also been a general increase in systems needing more compute power and the need for an increase in compute density at the same time that have driven many of these purchases. This highlights another major aspect driving the adoption of multicore-based systems — the inherent ability to gain computing power while maintaining or reducing the consumption of electric power.

**Server population installed base.** Approximately 2 million multicore servers have shipped since 2003. However, dual-core/multicore processor hardware is hardly a dominant form factor when one considers usage among the overall installed base, which today includes almost 30 million servers installed around the globe. This number is expected to change rapidly. Multicore systems accounted for over 30% of systems sold in 2006 and are expected to account for over 80% of systems sold in 2007.

## Software Readiness

**Commercial threaded software.** Modern server operating systems and most server applications are designed to run in multiprocessor/multisocket systems. IDC believes the addition of multiple cores per processor/socket will impact workloads in two ways. One will be the increase in raw compute power while maintaining or reducing the electrical power required. The other will be the added flexibility and option to target workloads to specific cores or sets of cores via virtualization.

Multicore technology certainly has been the focus of a great deal of marketing attention over the past few years as server vendors positioned the technology for performance-oriented workloads where throughput matters a great deal. These workloads represent 62% of the spending for all scalable SMP servers with eight or more processors today and include database, business processing, business intelligence/decision support, and technical/high-performance computing.

ISVs for these applications typically include the following:

- **Database.** This workload segment is highly consolidated, with Oracle, IBM, and Microsoft dominating the market today.
- **Business processing.** Increasing consolidation in this workload segment, where PeopleSoft, JD Edwards, and Siebel have all been acquired by Oracle, pits the latter firm against SAP.
- **Technical/high-performance computing.** This workload segment is not terribly consolidated, but large players include Synopsis, Cadence Design, Mentor Graphics, Autodesk, Fluent, and Dassault.
- **Business intelligence/decision support.** An emerging area, this workload segment includes offerings from SAP, Oracle, IBM, Microsoft, Business Objects, SAS, Hyperion, and Teradata.

In addition to running the preceding business applications, quad-core processors are ideal for the following array of evolving Web services:

- **New architecture.** The architecture behind Intel's quad-core technology is the new Intel Core microarchitecture, and it delivers benefits to software applications regardless of how well threaded they are. Two key features are the wide dynamic execution engine with four instructions per clock and large on-die cache, which can improve application throughput by 33% and reduce system latency by relying less on the memory subsystem, respectively.

- **Added platform enhancements.** Intel's quad-core technology delivers processing speeds of up to 2.66GHz with bus speeds of up to 1,333MHz and, when coupled with other platform-level innovations, can provide performance headroom for unpredictable server workloads and escalating computing needs. These platform-level innovations also include up to 64GB of new fully buffered DIMM memory at 667MHz and accelerated I/O capability called Intel QuickData Technology.

- **Software development.** Quad-core technology can also be leveraged to accelerate application development and testing by utilizing virtualization and running tasks in parallel. This capability provides the opportunity to eliminate redundant systems and associated overhead, lowering total cost of systems and resources.

## IT and Business Benefits of Multicore, Multithreaded Systems

In 2005, IDC conducted the *Software Licensing in Multicore, Multithreaded, and Virtual Environments* study (IDC #05C4547, September 2005). The respondents' motivations for deploying multicore or dual-core processor hardware were generally focused on reducing effort and maximizing resources. Organizations cited a reduction in administration as a clear benefit of multicore hardware due to the reduction in the number of physical servers in the datacenter. Another benefit was the ability to increase processing output per square foot and therefore put more processing power in the same — or smaller — physical space. Lessened complexity is also a touted benefit. For example, companies noted that having two or more processors on the same motherboard provides a potentially less complex environment than having two separate servers for the application and also provides a more robust environment.

### *Energy*

The worldwide installed base of servers is at an all-time high of over 30 million units, and as a consequence, many IT organizations are struggling with rising power costs, inadequate cooling systems, and a strong desire to contain the datacenter footprint.

As the issue of power and cooling has become significant to the enterprise, datacenter managers must now pay closer attention to certain factors that will influence the cost of running the IT infrastructure. Two scenarios that illustrate the key IT decision factors of power consumption and cost of electricity are as follows:

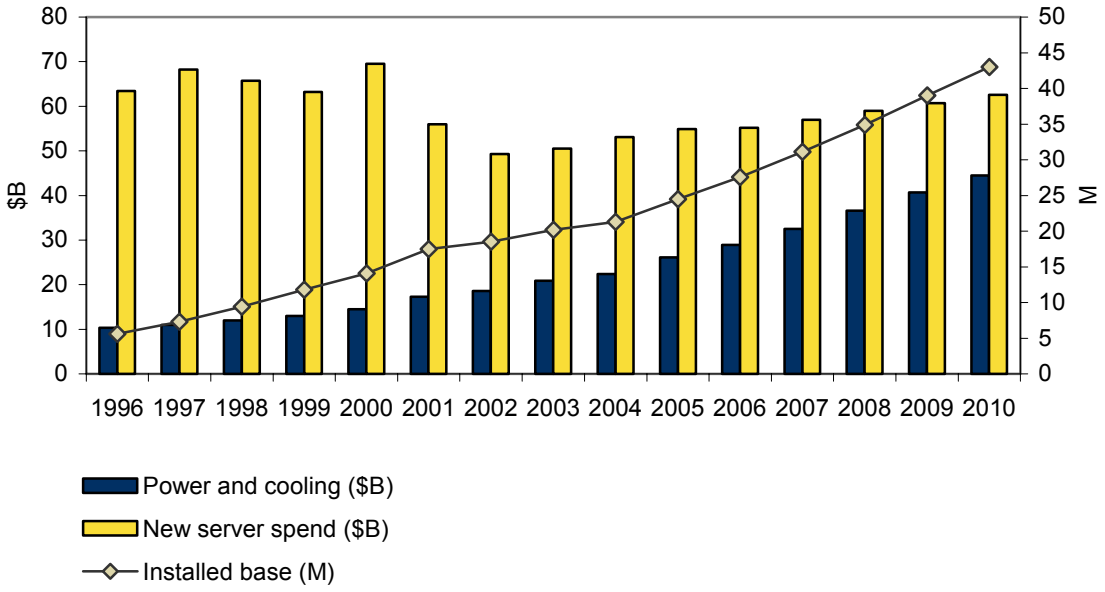
- An enterprise currently manages 1,000 servers (typical mix, with vast majority being x86 and the rest in order of RISC, EPIC, and CISC). Based on 2005 data, the four-year cost to power and cool these servers is $3.8 million. A 2% annual rate increase in the cost of electricity would raise this cost by almost $200,000 (a 5% increase).

- To meet business growth expectations, the same enterprise expects to double the server count in the next five years. During that time frame, if the enterprise steadily deploys new servers (which are expected to gradually increase each year in power consumption), the five-year electrical expense will be $9.1 million. If the enterprise is able to keep the average power draw constant by deploying more energy-efficient servers, the expense will fall to $5.2 million (a 44% cost savings).

On a global scale, Figure 2 provides a graphical view of the expense to power and cool the installed base of servers and the new server spending from 1996 through 2010. It also overlays the server installed base for the same time period. The data illustrates that for $1.00 of new server spend in 2005, $0.48 was spent on power and cooling. This is a sharp increase from 2000, when the ratio was $1.00:$0.21. The ratio is projected to rise to $1.00:$0.71 in 2010. (Note: Some managers of large datacenters surveyed by IDC are already saying that their spending on power is equal to their server spending.)

**FIGURE 2**

Worldwide Expense to Power and Cool the Server Installed Base, 1996–2010




Source: IDC, 2007

Quad core–based systems provide the capability to increase compute power three times to five times while controlling both energy requirements and space requirements relative to single core–based systems.

### *Space Efficiency*

Over the past decade, enterprises have worked to gain better control over the space they use in their datacenters. Toward this goal, in 1999, the rack-optimized form factor began to ramp up and help datacenter managers save server footprint. Thus, by 2003, the installed base of rack-optimized servers surpassed that of non-rack-optimized servers. Likewise, blade servers were introduced in 2002 as the new space-saving solution to rack-optimized solutions. Blades are the fastest-growing

form factor and have grown from 3.5% of the market in 2003 to 8.4% of the market in 2006. While quad-core processors will be used in all form factors, they will be especially important in smaller form factor rack-optimized and blade servers as IT optimizes performance within constrained power and space budgets. The combination of low power and high performance will maximize the potential to more efficiently utilize available space and control power requirements.

### *Virtualization*

In addition to smaller more powerful servers, virtualization offers IT the ability to boost space efficiency by improving utilization of each server and/or consolidating existing datacenters to reduce their footprint and energy consumption. Quad-core processors offer IT the ability to achieve these critical cost savings while improving application response time.

Virtualization or virtual machine (VM) software encompasses many different ways to partition resources, such as allowing multiple operating systems to run on a single processor, making a group of resources look like one resource (virtual storage or clustering), and making remote resources appear as if they were local resources. Virtualization can also have a hardware assist, such as Intel Virtualization Technology (Intel VT). The Intel quad-core processors discussed in this paper contain Intel VT. This layer of software hides the type of computer or computers that are actually supporting the work. Virtual processing software offers a spectrum of capabilities ranging from making a single machine look like many for some purposes to making many machines look like a single computing resource for other purposes.

Largely, this layer of software helps organizations satisfy their need for raw performance, scalability, reliability/availability, and optimization of the use of available systems or helps organizations create a unified single management domain. However, different products are needed to achieve each of these goals.

IDC completed a virtualization study in 2006 that showed a rapid increase in virtualization adoption in x86-based servers. Fifty percent of the study respondents had deployed VMs, with over 50% of those servers running production-level applications. This finding shows that virtualization on x86-based systems is broadly accepted as a mainstream technology.

### *Power Consumption and Heat Dissipation*

IT organizations know that they must support more demanding workloads with more powerful server systems and that, at the same time, datacenters are expensive to build and to operate. According to IDC forecasts, U.S. datacenters alone will house 50% more servers by 2009. IDC estimates that the cost of electrical power for the 40 million servers in use in 2009 will be in excess of $5 billion per year, and this estimate does not take into account the cost of cooling. Reductions in the size, electrical power, and cooling requirements for servers can have a significant impact on both capital expenses for new datacenters and operating expenses for existing facilities.

With each passing year, servers are physically smaller in size (i.e., compute density is rising); however, power consumption and cooling requirements continue to grow. The major culprits are the multiple single-core processors within the servers, which require

more electrical power and produce more heat than ever before. Increasing power requirements drive the need for larger power supplies and more in-server cooling. Today, racks of servers can require 8kW to 12kW of electrical power, which increases the construction costs as well as the operating costs of the datacenter. This requirement will only increase as new processors make it into the next generation of servers such as server blades. Customers also need to consider the amount of power that their utility provider is able to deliver to the datacenter. In some instances, especially in densely populated business districts, no more than 1kW can be delivered to a rack.

With these factors in mind, IT organizations are increasingly concerned with the amount of computing throughput they can deliver in a cost-effective power and thermal envelope. Performance per watt is emerging as a key metric when choosing the right servers to meet the workload requirements for the enterprise as well as fit within the datacenter conditions.

### *Performance per Watt*

The Quad-Core Intel Xeon processor 5300 series delivers new levels of performance per watt in the x86 server market. With a performance level that is three times to five times greater than that of single core–based systems and similar power requirements, the quad-core processor realizes a performance per watt improvement of three times to five times that of the single-core processor. The Quad-Core Intel Xeon processor 5300 series is available in three power ranges: 120, 80, and 50 watts. The 80 watt processor represents the majority of Intel quad-core products and was used for the comparisons in this paper. The 120 watt version provides more performance for the most demanding applications, while the 50 watt processor provides the lowest power for power-constrained environments while still maintaining performance that is equal to that of the 80 watt version at a slightly higher price.

## Major Performance Increase Over Present Single-Core Architecture

The focus of this paper is a comparison of quad-core processors and single-core processors because the latter will be the typical system replaced by the former. The following customer snapshots contain some references to dual-core processors.

### *Customer Snapshots*

#### Intel IT: Server Consolidation Using Quad-Core Processors

Intel IT used the Quad-Core Intel Xeon processor 5300 series to consolidate test workloads from eight physical machines into VMs running on a single server.

The dual-socket, quad-core server completed the workloads 66% faster than the original eight servers based on the Pentium III processor, using 86% less power per workload. The quad-core processors were also 34% faster than the Dual-Core Intel Xeon processor 5148 running the same consolidated workloads. On quad-core processors, Intel IT found that workload completion times remained much more uniform and predictable as the number of workloads increased.

The results show the strong potential of the Quad-Core Intel Xeon processor 5300 series for high levels of consolidation and virtualization, particularly with CPU-intensive applications. Intel anticipates that each 8:1 server consolidation could save about $6,024 a year in direct operating costs, based on support, network depreciation, and power and cooling.

#### BMW Automobiles: Service Department System Consolidation

BMW Automobiles is known for its premium products and services. The company began looking at quad core–based systems to provide a platform to consolidate and enhance its ability to provide and track cars as well as services needed and completed on its cars. The company's current service environment is made up of multiple systems to run diagnostics, parts management and tracking, car ID/tracking, and so forth. BMW Automobiles has been working on a five-year cycle to update/modify the service environment at its dealerships.

The company's goal was to develop a client/server environment in which it could consolidate all of these applications and improve the creation and management of this data. Currently BMW Automobiles has multiple independent systems. It ran lab tests to prove the capability and viability of the systems. The combination of quad-core performance and virtualization gives the company the tools, along with a cost structure, that makes this work. Their analysis showed a compelling cost reduction as well a gain in productivity, which, while more difficult to quantify, is of equal importance to or greater importance than the pure cost analysis. Using virtualization, the company can load disparate applications and run them successfully. It only needs to access, collect, and manage data, not fully synchronize software programs, which reduces the burden on IT significantly. BMW Automobiles is working with 30-plus years of data as well as planning for change over the life of the systems.

To put some context around the added value of quad-core versus dual-core processors, the company estimated that dual-core processors would need to be replaced around the middle of the planned five-year cycle while quad-core processors would provide the company with enough headroom to cover the full cycle. These new systems will be rolled out to BMW Automobiles' 3,000+ dealers around the world.

### *Services Support*

Intel Solution Services helps customers break through the barriers to technology adoption, including the adoption of quad-core systems in the datacenter. Through solution and service offerings, Intel assists customers in evaluating existing datacenter computing resources and infrastructure and planning for technology transitions. Intel Solution Services helps customers who are considering the adoption of quad-core processors through their assessment, planning, and implementation requirements for consolidation, standardization, and IT automation strategies — all key issues for customers who are planning to virtualize computing resources, reduce power and thermals, and automate IT operations.

### *Ecosystem Support*

The leading hardware and software vendors are supporting Intel quad-core processors. The major system vendors, such as Dell, Fujitsu/FSC, IBM, HP, NEC, and Sun, either can leverage existing systems or are building new systems around this architecture. Major software vendors, both ISVs and OSVs, including Microsoft, Oracle, Red Hat, IBM, BEA, SAP, SAS, Novell, VMware, Symantec, Sybase, SunGard, and Schlumberger, among others, are supporting the architecture as well.

In addition and equally important, Intel has built a comprehensive line of software tools to aid in the development and continued optimization of software for this environment. Intel developed a multicore curriculum adopted by over 40 universities, with over 7,000 students trained. It has touched over 400,000 developers through various outreach programs, all in an effort to prepare the broader industry for realizing the full benefits of adopting multicore systems. As a result, the majority of current enterprise server software will run without code changes and deliver excellent performance scaling on today's quad-core processors.

## IDC ANALYSIS: CHALLENGES AND OPPORTUNITIES

Looking forward, Intel quad core–based systems face some challenges as well as very significant market opportunities. The challenges fall into two major categories: market dynamics/readiness and technical challenges.

**Software licensing models.** The needs for new software pricing strategies and end-user acceptance are altering the market dynamics. A 2005 IDC study entitled *Software Licensing in Multicore, Multithreaded, and Virtual Environments* found end users divided on software pricing going higher or lower in this new environment. IDC believes this pricing will not have a major impact on adoption of the technologies. End-user acceptance is being aided by the momentum in virtualization adoption as well the general readiness of server software from almost all major ISVs, plus most server applications are already threaded. The era of multicore computing is changing the dynamics of software pricing throughout the industry. IDC encourages users to have open dialogue on their expectations and needs for equitable licensing policies that provide a positive business value for adopting multicore systems.

**Software performance scaling.** Intel needs to continue its development of software tools and training across the industry and in academia. The major technical hurdle is related to high-performance single-threaded applications. In some extreme cases, they will run better on dual-core processors than on quad-core processors driven by lower latency inherent to lower core counts. High-performance single-threaded applications are a very small part of the market, and this segment is served by Intel's varying core count offering today.

**Adapting single-threaded applications.** Another possible obstacle is the older single-threaded business applications. However, the performance requirements of single-threaded applications are such that they are generally well served by utilizing virtualization technology and loading multiple applications on a single system. As a result, the vast majority of applications can leverage quad-core processors either by being threaded or utilizing virtualization to consolidate multiple applications on a single server.

**Microsoft virtualization solutions.** Another technology that could impact quad-core adoption is Microsoft's next generation of virtualization on its new server operating system, which is expected to enter the market in 2008. This offering is expected to increase the acceptance of virtualization and be a positive factor in quad-core adoption.

This paper describes numerous reasons for the adoption of quad-core processors, including outstanding compute performance, price performance, and new levels of performance per watt. As the next-generation Intel Xeon processor enters the market, a very large quantity of existing applications will run without modification. These attributes, along with high application availability, should make this new architecture very appealing for new one- and two-socket system purchases.

## CONCLUSION

Intel has created a market-leading processor family built on quad-core technology with a first-to-market advantage. Leading hardware and software vendors have expressed and exhibited full support. Early tests by a significant cross section of end users have proven the value and efficacy of the architecture. Intel has provided a foundation of software tools and industry training to accelerate industry readiness and adoption. Most server applications can already leverage the key quad-core attributes, and server virtualization software with hardware assist makes application consolidation a key usage model.

The value proposition for Intel quad core processor–based systems is clear. They outperform existing systems in all three major areas: compute performance, price performance, and performance per watt. As one of the HPC users commented, "Moving from dual core to quad core is a no-brainer." And the move from single core to quad core is even more compelling.