



## Real-World Benefits of Throughput Computing with UltraSPARC IV+

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### PREPARED FOR

Sun Microsystems

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### Executive Summary

Sun Microsystems (Sun) has built a loyal base of customers who have benefited greatly from the technological innovation Sun has exhibited over the past 20 years. As the leading supplier of UNIX-based systems, Sun has been the target of competing vendors' attempts to dislodge Sun from its position as the preeminent UNIX provider. In recent years, many of those attacks have focused on indicators of processor performance.

However, Sun does not need to be apologetic about its processor designs. In fact, Sun is now spearheading the movement to design processors that emphasize system throughput and economical operation, rather than just ever-faster clock frequencies. At the heart of this revolution in processor design is a focus on what Sun terms Chip Multithreading Technology (CMT).

Sun introduced CMT with the UltraSPARC IV processor, launched in February 2004. That design was recently enhanced with UltraSPARC IV+. Those chips deliver customer-usable throughput for midrange and high-end servers through a combination of CMT and advanced system design. Table 1 (above) indicates the wide range of currently shipping Sun Fire servers incorporating UltraSPARC IV+, from the lower-midrange V490 through the enterprise workhorse E25K. In addition, many existing Sun servers can be upgraded with the addition of the new processors, a longstanding Sun practice that customers cite as a great benefit.

Complementing UltraSPARC IV+, Sun has introduced the UltraSPARC T1 for a new line of SPARC-based servers. Previously known by its code name "Niagara," UltraSPARC T1 offers greater levels of CMT for highly parallel environments engendered by the growing Internet, such as web serving, searching, video streaming, etc. Together, UltraSPARC IV+ and UltraSPARC T1 reinvigorate Sun's UltraSPARC server line, enabling Sun to strengthen its market position.

Although some might consider the new design approach for the processor chips revolutionary, customers will view the results of UltraSPARC IV+ as evolutionary. Clearly, they will benefit from the higher throughput and lower power and space requirements delivered by CMT chips. But as an added benefit, customers will not

Table 1.  
Sun Fire Models Featuring UltraSPARC IV+

System	Maximum Chips, Threads
Sun Fire V490	4, 8
Sun Fire V890	8, 16
Sun Fire E2900	12, 24
Sun Fire E4900	12, 24
Sun Fire E6900	24, 48
Sun Fire E20K	36, 72
Sun Fire E25K	72, 144

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## PERFORMANCE IS MORE THAN CLOCK FREQUENCY

Over 40 years ago, Gordon Moore (then with Fairchild Semiconductor) noticed a trend involving manufacturing cost and circuit density and reported his observations in an article titled "Cramming More Components onto Integrated Circuits."<sup>1</sup> Over the decades, one popular interpretation of what became known as Moore's Law focused on smaller circuitry's ability to facilitate ever-increasing processor clock rates with the associated performance gains. Admittedly, faster clock rates have delivered phenomenal performance improvements over the past decades. However, electrical power consumption and thermal dissipation issues are now becoming an impediment to engineers who previously depended primarily on higher frequencies to drive chip performance. Consequently, designers now look to make more efficient use of the large number of circuits available on today's processor chips.

As a historical illustration, in 1995, two processor chips tied for delivering the most floating-point performance. Digital's Alpha 21164 and IBM's POWER2 each measured 12.4 SPECfp95. The Alpha chip ran at 300 MHz while the IBM chip ran at 77 MHz, a nearly four to one difference in clock speeds. The two approaches, dubbed "speed demons and braniacs" by analysts, illustrated that processor logic design played as important a role as clock frequency. Over the next decade, costly investments in state-of-the-art semiconductor fabrication facilities enabled clock rates to be cranked up to over a gigahertz. Although design diversity still existed, most competitive chips came to operate at similar frequencies. The clock rate became a simple gauge of performance for customers not interested in diving into implementation details. Now that power and thermal considerations limit the unbridled increases in clock rates, innovative design will play an increasingly larger role in determining performance. In what may seem a return to the past, customers need to look at the productivity a processor chip actually delivers and not use frequency as a proxy for performance.

<sup>1</sup> Electronics, Volume 38, Number 8, April 19, 1965. A copy of this article can be found at [www.intel.com/pressroom/kits/events/moores\\_law\\_40th/](http://www.intel.com/pressroom/kits/events/moores_law_40th/).

be required to make software changes to take advantage of the new processor designs. Sun has preserved binary compatibility and the shared-memory programming model, enabling customers to embark on a straightforward and painless migration to the next generation of processor designs.

This white paper explores the advantages of CMT as implemented in UltraSPARC IV+. Ideas International (IDEAS) examined the new capabilities offered by Sun's latest enterprise server processor and then interviewed a sample of customers who had received early shipments of servers powered by UltraSPARC IV+. The feedback from those early adopters confirms that UltraSPARC IV+ offers a non-disruptive path to greater system performance and throughput. Customers seeking high-throughput Solaris computing systems should seriously explore how UltraSPARC IV+ can help them achieve their goals, and make plans to incorporate Sun's CMT technology into their environments.

## Introduction

As the sidebar ("Performance is More Than Clock Frequency") explains, processor designers can no longer depend solely on faster clock rates in their quest to deliver additional performance. Electrical power consumption and the resulting thermal dissipation concerns have become important design considerations that require innovative approaches. Furthermore, memory access constraints mean that higher processor frequencies do not always provide improved system throughput.

Sun, with its Chip Multithreading Technology (CMT) designs, has now taken the lead in creating processor chips that deliver high throughput at efficient power/thermal levels. Sun's UltraSPARC IV and UltraSPARC IV+ processors implemented its first CMT designs. This paper explores the advantages of servers employing those implementations and offers customer perspectives gathered from a few users of those processors. Recently, Sun launched a new processor design with even greater CMT, previously code named "Niagara." Although this paper may mention various CMT options, customer experience with the UltraSPARC T1 implementation is not part of this study, since servers using that new design are just beginning to ship.

Over the years, Sun's UltraSPARC has been the most widely used processor family for UNIX workstations and servers. Sun customers are quick to point out that the binary compatibility offered by UltraSPARC and Solaris has enabled them to easily upgrade across processor generations. The recently released UltraSPARC IV+ represents the latest high-performance processor chip in this family. UltraSPARC IV built upon the successful UltraSPARC III design point and introduced the parallel capabilities of CMT. UltraSPARC IV+ refines UltraSPARC IV with enhancements that provide a higher-performing CMT implementation. The throughput performance of UltraSPARC IV+ CMT is ideal for the traditional UNIX environments typically deployed on midrange and high-end servers. This paper focuses on how UltraSPARC IV+ brings CMT performance to typical midrange and enterprise UNIX environments.

## MULTICORE/MULTITHREAD AND SOFTWARE LICENSING

For many years, microprocessor engineers focused on designs that accelerated the execution of a single task, and each processor chip contained one core that ran one thread at a time. As the prior sidebar (Performance is More than Clock Frequency) points out, engineers now strive to balance power consumption with single-thread performance, and have created innovative multicore, multithread designs.

All major processor families either have already incorporated multicore designs or plan to do so in the near future. However, the implementations are all somewhat unique and there has not been a standard terminology adopted by the industry. In fact, there are many terms used to describe the attributes of microprocessors, such as processors, chips, cores, threads, and sockets.

The complete collection of circuitry needed to execute code is called a core. When the execution of a sequence of instructions cannot proceed, while awaiting data from memory or disk, the hardware execution units fall idle. A multithreaded design tries to keep the hardware execution units busy by quickly switching to a different instruction stream from a different program. To illustrate, an UltraSPARC IV+ processor chip contains two cores and two threads, while an UltraSPARC T1 includes eight cores and 32 threads.

Back in the days when processors were single core and single thread, many independent software vendors (ISVs) based their licensing on the number of "processors." (Other ISVs licensed their applications based on the number of users.) Now that processor designers commonly implement multiple cores and multiple threads on each chip, the entire software industry is struggling to develop a licensing strategy. Some software providers have begun to employ a pricing factor that applies only a fraction of a full license to each core. Other ISVs are reexamining user-based pricing.

New technologies like the UltraSPARC T1 will undoubtedly focus more attention on software licensing in 2006. Revised ISV licensing policies will benefit all multicore, multithread implementations, including the UltraSPARC IV+.

## What Is UltraSPARC IV+?

The fundamental UltraSPARC III design was first introduced in Sun workstations and low-end servers in late 2000 and rolled out to midrange and high-end systems in early 2001. The same underlying design forms the basis for UltraSPARC IV and UltraSPARC IV+, thus assuring non-disruptive application migration across chip generations.

Over the years, Sun incrementally enhanced its UltraSPARC III platforms, increasing the clock speed from 750 MHz to 900 MHz, then to 1.05 GHz, and ultimately to 1.2 GHz. A unique advantage of Sun's midrange and high-end servers has been their ability to support different speed processors in the same server or dynamic system domain (domain), thus allowing customers to incorporate new processor technology within existing servers. (Domains are Sun's hardware partitions that are available in the Sun Fire 4800 to the Sun Fire Enterprise 25K.)

The semiconductor fabrication advances underlying Moore's Law will continue to bring increased processor chip circuit density and the opportunity for faster frequencies. However, faster clock rates will no longer be the primary source of improvements; instead, the manner in which extra chip circuits are used will play an increasingly important role in delivering overall system performance. Hence, with UltraSPARC IV, Sun introduced CMT as a way to use that circuitry to dramatically increase the throughput of each processor chip without having to increase frequency.

Note that processor engineering teams consider a spectrum of different design tradeoffs when determining how to best employ the available chip circuits. As discussed in the sidebar, "Multicore/Multithread and Software Licensing," the nomenclature describing the diversity of implementations has not yet become consistent. More importantly, software providers are struggling to decide on licensing terms for multicore and multithread implementations. Despite some current confusion, multicore/multithread processor designs will soon become commonplace in servers ranging from entry level to enterprise class.

UltraSPARC IV incorporates two full sets of UltraSPARC III logic on the same processor chip in speeds up to 1.35 GHz. That combination offers the potential for a near doubling of throughput by allowing two instruction streams, also called threads, to be executed simultaneously. However, implementing two full sets of circuitry on the same processor chip does present some challenges. Since the physical packaging retains essentially the same number of pins connecting the processor chip to the system board, the two sets of circuitry, also called cores, share the same bus to external cache and memory. Depending upon the application workload, the bus-sharing and splitting of the cache between the dual cores can limit the throughput to slightly less than twice that of UltraSPARC III.

UltraSPARC IV+ moves from the 130 nm fabrication process of UltraSPARC IV to a 90 nm semiconductor manufacturing process. The 90 nm process provided substantially more circuits per chip, which allowed Sun engineers to improve the dual-core design to increase performance while maintaining full binary compatibility. Among the improvements, Sun engineers significantly enhanced the UltraSPARC III core design and added an internal Level 2 (L2) cache and a large

external Level 3 (L3) cache. Per Sun, the resulting UltraSPARC IV+ chip contains over four times as many transistors as UltraSPARC IV (295 million transistors compared to 66 million) yet fits on a slightly smaller silicon die and consumes less power than its predecessor.

UltraSPARC IV slightly enhances the UltraSPARC III core by refining the floating-point unit and write cache. UltraSPARC IV+ significantly improves the UltraSPARC IV design in the instruction prefetching, instruction caching, instruction translation buffers, and branch prediction buffers. The data caches, data translation buffers (TLBs), and write cache are further improved with UltraSPARC IV+. Some of the improvements include four-times larger TLBs and support for larger memory pages. Many of the above improvements are aimed at enhancing memory access so that the processor threads can run at higher efficiency. At the same time, circuitry was added to enhance detection of error conditions. The result is a core design with better thread performance and higher levels of reliability that remains compatible with prior UltraSPARC binaries.

Perhaps even more significantly, UltraSPARC IV+ adds an on-chip 2 MB L2 cache. An on-chip L2 cache offers far lower latency and much higher throughput than the external L2 previously employed. In place of the prior external L2, Sun has added a shared off-chip 32 MB L3 cache for UltraSPARC IV+ systems. The combination of a fast on-chip L2 and a large off-chip L3 can dramatically improve performance for many applications. Refinements to the on-chip memory controller improve latency and bandwidth. And, once again, all these enhancements preserve binary compatibility and the shared-memory programming model.

The design enhancements of UltraSPARC IV+ offer a substantial performance boost over UltraSPARC IV (and UltraSPARC III) even without an increase in frequency. The move to 90 nm technology permits clock rates to increase while staying within the same power and thermal envelope of prior chips. Initial UltraSPARC IV+ chips run at 1.5 GHz; faster clock rates are anticipated once the manufacturing process is tuned. Taking into account the faster clock rate of UltraSPARC IV+, Sun's latest CMT chips promise a dramatic jump in performance for existing UltraSPARC III and UltraSPARC IV users. Furthermore, most UltraSPARC III and UltraSPARC IV customers are able to deploy the new UltraSPARC IV+ processors in their existing servers, providing a smooth upgrade path and excellent investment protection.

As previously mentioned, the new UltraSPARC IV+ processor provides a substantial performance boost over existing UltraSPARC III and UltraSPARC IV-based systems. However, this performance boost does not require any increase in datacenter floor space and only minimal increases in power and cooling. Moving to UltraSPARC IV+ from UltraSPARC III or UltraSPARC IV provides better throughput per watt and per floor-tile space. For some customers this switch may result in reduced real estate and environmental costs.

## System Improvements

In multiprocessor systems, the performance is a function of I/O capability, processor speed, and the capacity of the system interconnect. To get the maximum benefit of a new and faster processor, the system interconnect – the internal

## SPECJBB, SPEC'S JAVA SERVER BENCHMARK

The member organizations of non-profit SPEC (Standard Performance Evaluation Corporation) work together to define standardized benchmarks to help gauge computer system performance. SPEC develops and maintains the benchmark suites and also reviews and publishes submitted results.

SPEC has developed a Java Server Benchmark, SPECjbb, to evaluate the performance of server-side Java by emulating a three-tier configuration. SPECjbb2000 was its first server-side Java benchmark and has been measured on a number of platforms over the past few years. SPECjbb2005 incorporates an enhanced workload that more realistically reflects the way current applications are designed to use the latest JVM and Operating System features. As a relatively new benchmark, only a few results have been reported on SPECjbb2005.

network that moves data between the disk, network, and memory to the processors – must have sufficient capacity so that the processors always have enough data to work on. A slow interconnect can handicap a fast processor and reduce its efficiency.

Sun first recognized the importance of fast system interconnects with the introduction of the Enterprise 10000 (E10K) in the mid-90s. To get superior total system performance requires a balanced system with fast I/O, fast processors, a high-capacity interconnect, and a multithreaded and efficient operating system. To make sure that Sun Fire servers could support ever faster processors, the interconnects in the Sun Fire servers were designed to handle much faster processors than were available when the servers were first introduced. Also, Sun has made incremental system improvements over the years to the Sun Fire servers. These include faster I/O subsystems, interconnect improvements, and Solaris improvements designed to ensure better internal data management in larger SMP systems.

The benchmark and customer examples presented in the following sections clearly show that the Sun Fire servers do have fast enough system interconnects and I/O subsystems to support the faster UltraSPARC IV+ processors.

## Benchmark Evidence

Clearly, the best way for customers to determine the performance benefit of a new server is to run their own workloads on that system. Before testing their custom workloads on actual hardware, customers often look to industry-standard benchmarks to give them a rough gauge of what to expect.

Although UltraSPARC IV+ has only recently been introduced and benchmark measurements are just beginning to be reported, the initial results confirm the potential boost offered by CMT and the enhanced processor design. Among the results reported by Sun are SPECjbb2000 and SPECjbb2005 (see the sidebar “SPECjbb, SPEC’s Java Server Benchmark”).

Since Sun has measured SPECjbb2000 on many of its servers, that benchmark can illustrate the performance improvements across generations of UltraSPARC processors. As shown in Figure 1 (next page), the measured SPECjbb2000 of Sun Fire 6800/E6900 has dramatically improved over the past few years. Table 2 in the Appendix provides the details supporting Figure 1.

The two leftmost bars of Figure 1 (next page) show 24-processor UltraSPARC III results on a Sun Fire 6800. As the clock rate increased from 750 MHz to 900 MHz, the SPECjbb2000 exhibited a corresponding improvement. Then, when UltraSPARC IV was introduced with the Sun Fire 6900, there was a substantial jump in performance well beyond the increment in clock rate. The reason: UltraSPARC IV offers two full sets of instruction execution circuitry and is able to process two independent code threads simultaneously.

Note from the figure that UltraSPARC IV+ also provides a dramatic performance jump, greater than the increase in processor clock frequency. But since the tested Sun Fire systems with UltraSPARC IV and UltraSPARC IV+ have the same number

FIGURE 1

SPECjbb2000 for 24-Chip Sun Fire 6800, Sun Fire 6900

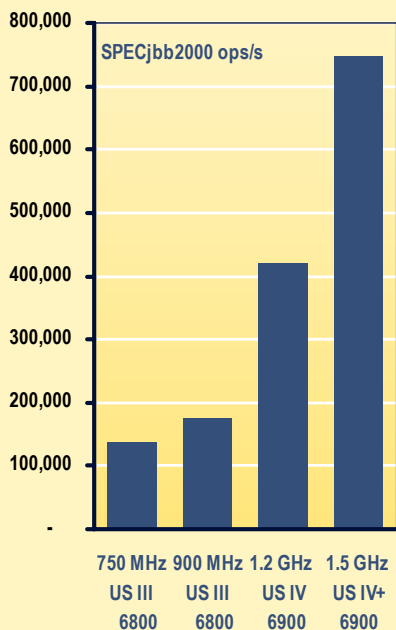
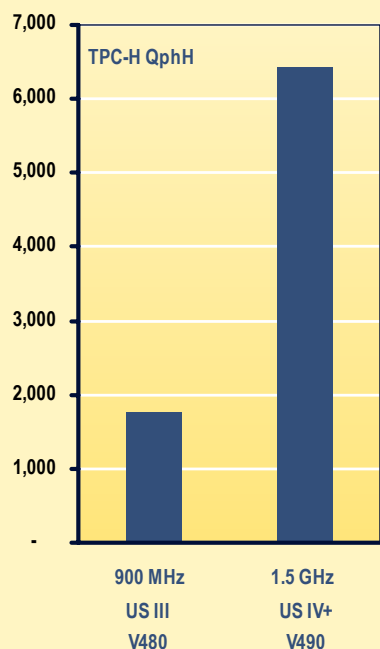


FIGURE 2

100 GB TPC-H for Four-Chip Sun Fire V480, V440, V490



of processor chips and the same number of active threads, something other than incremental clock frequency must be what delivers that performance gain. That UltraSPARC IV+ performance boost is due to the processor design enhancements outlined earlier, especially the on-chip L2 cache.

Recall that the 900 MHz UltraSPARC III Sun Fire 6800 shown in the chart can be non-disruptively upgraded, in-box, to the 1.5 GHz UltraSPARC IV+ Sun Fire 6900 depicted in the rightmost bar. Those upgrades can deliver up to five times more SPECjbb2000 performance for the same basic server, with the same number of processor chips.

The Sun Fire 6800/E6900 employs Uniboard processor/memory boards that contain the UltraSPARC processors. The Uniboard design is also used throughout Sun's midrange and enterprise servers, from the Sun Fire E4800 through the E25K. Although performance evidence has not yet been published for each of these Uniboard systems, users should experience dramatic performance jumps similar to the Sun Fire E6900 of Figure 1. And, remember that Sun supports mixed-speed and mixed-processor-generation Uniboard systems, so that existing Uniboard servers can be incrementally updated a board at a time without having to take down the entire server for an upgrade. If a server or a domain has Uniboards installed with different processor generations or processor speeds, each Uniboard will run at the rated speed of its processors. For example, 1.05 GHz UltraSPARC III processors will run at 1.05 GHz and 1.5 GHz UltraSPARC IV+ processors will run at 1.5 GHz. The Sun Fire V1280 and its UltraSPARC IV equivalent, the Sun Fire E2900, are not Uniboard-based systems, but they also support mixing all UltraSPARC processor generations from the 900 MHz UltraSPARC III to the new UltraSPARC IV+.

Customers must replace their Sun Fire V480 and Sun Fire V880 systems with new servers to take advantage of the UltraSPARC IV and UltraSPARC IV+ processors. Replacing these lower midrange systems with new UltraSPARC IV+ servers offers a similar performance boost. The UltraSPARC IV-based Sun Fire V490 and Sun Fire V890 support both the UltraSPARC IV and UltraSPARC IV+ processors.

Figure 2 demonstrates that a Sun Fire V490 with four 1.5 GHz UltraSPARC IV+ chips delivers more than 3.5 times the TPC-H QphH compared to a Sun Fire V480 with four 900 MHz UltraSPARC III chips. Supporting details are provided in Table 3 in the Appendix.

Figure 3 demonstrates that a Sun Fire V890 running 16 Java threads on eight 1.5 GHz UltraSPARC IV+ processor chips delivers greater than 50% more SPECjbb2005 throughput compared to the fastest UltraSPARC IV, measured using a 16-thread Sun Fire V890 with 1.35 GHz UltraSPARC IV chips. Both benchmark tests were run with the same software versions, as indicated in the Appendix Table 4. The small increment in clock speed certainly cannot account for the performance delta; clearly, the enhanced processor design of UltraSPARC IV+ delivers that throughput boost. SPECjbb2005 is a new benchmark; few results have yet been released to compare servers. However, also shown in Figure 3 is a recent SPECjbb2005 posting for IBM's POWER5+ p5-550Q. Running 16 Java threads – albeit on four dual-core/dual-thread chips – the POWER5+ result falls into the same range as Sun's UltraSPARC IV and UltraSPARC IV+. Figure 4 displays similar

FIGURE 3

SPECjbb2005 for 16-Java-Thread Sun V890 and IBM p5-550Q

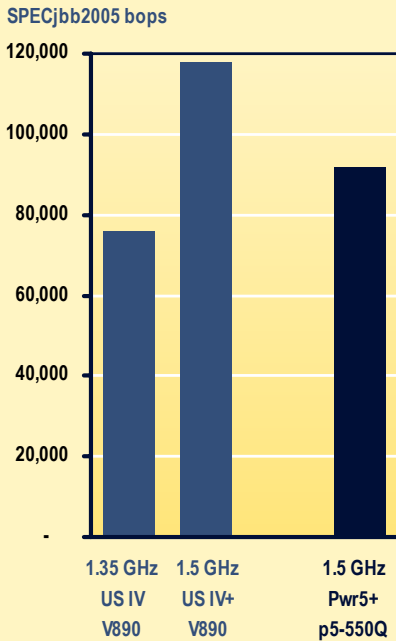
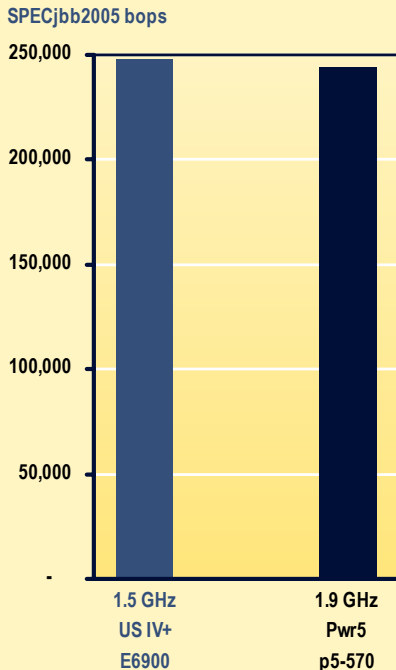


FIGURE 4

SPECjbb2005 for 32-Java-Thread Sun E6900 and IBM p5-570



results – using 32 Java threads, a 1.5 GHz UltraSPARC IV+ Sun Fire E6900 provides slightly more SPECjbb2005 bops than a 1.9 GHz POWER5 p5-570.

Although the performance benefits of UltraSPARC IV+, as implied by industry-standard benchmark results, do appear inviting, the overall benefits of moving to UltraSPARC IV+ are best related by those who have tested systems with the new chips.

### Early User Experiences

As part of our examination of the benefits of Sun’s UltraSPARC IV+ processor, IDEAS interviewed a few early users of systems powered by the new processors. The small sample of beta site users was not intended to cover all application areas but rather to obtain some early first hand feedback on what the upgrade meant to these users.

Overall, those we interviewed did confirm that systems based on UltraSPARC IV+ delivered substantial performance gains for their applications. However, the most important aspect in their minds was Sun’s commitment to maintain binary compatibility. That is, the early testers said they were pleased to evaluate the new processors because they did not have to change their software to undertake that evaluation. In fact, the customers we interviewed did not consider themselves as pioneers. As one said, they “do not want to be on the bleeding edge, especially if that requires an operating system change along with the hardware upgrade.” Universally, those we spoke with would advise other SPARC/Solaris users to make plans to upgrade to UltraSPARC IV+ – especially those with UltraSPARC III systems, in order to reap the large performance gains.

This section summarizes the early adopter perspectives that were offered during our one-hour interviews. The interview participants were asked to relate both their positive experiences as well as reveal any areas that did not meet their expectations. They were told that their comments could remain anonymous. Overall, their feedback was overwhelmingly positive and most customers did not object to being identified. However, many said that their corporate policy required formal approval of any attributed quotes. To minimize that review cycle, we have not directly identified the individuals and firms in this whitepaper.

A customer with a variety of business applications on his production systems observed that moving from UltraSPARC IV to UltraSPARC IV+ provided 1.5 to 1.7 times better performance for some applications while other applications saw 2.5 times the performance. He noted that codes that were multithreaded got a better return while those that were I/O constrained saw the least performance gain. He noted that some applications, including some third-party products, were still single threaded, but those were not in his critical performance path.

A long-time user of Solaris-based applications tailored to his industry has enjoyed 20% annual growth rates over the past few years and anticipates similar growth in the future. Much of his business comes from clients linking over the Internet. If they find his servers busy due to workload peaks, then they may go to his competitors. His initial approach was to add processors to his three Sun Enterprise 6500 servers, which employ UltraSPARC II processors. But once he had reached

maximum capacity of his Sun Enterprise 6500 configurations he looked to upgrade to Sun Fire E6900 servers. Benchmarking with his own workload, he determined that a Sun Fire E6900 with eight dual-thread UltraSPARC IV chips delivered 80% more performance than his 24-processor Sun Enterprise 6500. He replaced his three maxed-out Sun Enterprise 6500s with two Sun Fire E6900s, each with only eight processors. This customer said that the move to UltraSPARC IV CMT was “really easy” since there were no changes required to his applications and he could continue on the same level of Solaris. He now feels he has adequate capacity to meet workload peaks. His next step is to move to UltraSPARC IV+. His testing with those new processors showed that UltraSPARC IV+ would provide at least an additional 40% increase in throughput. Since he now has adequate capacity with UltraSPARC IV CMT, as part of his move to UltraSPARC IV+, he plans to upgrade to new versions of his application software and his database as well as move to Solaris 10 and explore Solaris Containers. (Note that while UltraSPARC IV+ processors support Solaris 9, this customer will move to Solaris 10 when he moves to UltraSPARC IV+ to gain the advantages of this latest version of Solaris.) Testing of those software migrations will likely require six to eight months and then he can deploy his production workloads on UltraSPARC IV+ to gain the 40+% extra performance. That additional performance should address his growth for a couple years, and then he can add more UltraSPARC IV+ processors to his Sun Fire E6900 servers. His recommendation to others: “If you have any performance constraints, immediately upgrade to UltraSPARC IV or IV+.”

Another customer was quite pleased with the ease at migrating from single-thread processors to dual-thread UltraSPARC IV+ systems. His comment: “Sun’s architecture allows my business to continue to operate, and move forward, without any disruption, and immediately realize added value. Later on my time scale, I can go back and reinvest to get even better performance wins with some minor modifications and tweaking.” Going from UltraSPARC III to UltraSPARC IV+ he said he immediately saw a doubling of performance with zero modifications to current code. He continued by saying that over the past more than five years that his fairly complex processing environment has not been disrupted. “It has been a huge win to move from family to family, or moving within a family to the next iteration, and being able to realize a true throughput benefit without any recoding.”

One customer observed that many vendors would brag about the performance of their latest processor chip when running a commonly used application. He wonders if there really are many users who only run system-agnostic applications and who might easily change hardware and operating systems to chase the fastest processor chip as vendors leapfrog each other. This customer stated that he has in excess of 100 applications that he needs to verify before committing to production. His highly tuned production environment includes a proprietary internally developed database and I/O-intensive code that is crucial to his operation. He does not want to have to modify his code to install new hardware and hopes to avoid hardware upgrades that require concurrent operating system upgrades. He emphatically stated he does not want to face the disruptive move to a new operating environment. Sun’s binary compatibility has been very important to him. His testing of UltraSPARC IV+ only required a couple of minor tweaks to his internally developed applications. On average, he saw a doubling of performance when moving to UltraSPARC IV+, with various applications achieving from 1.5 to 2.5 times greater performance. Even with fully compatible chips and a fully compatible

operating system, he feels he needs six months to a year of Quality Assurance testing before he is ready to commit the lion's share of his production to upgraded systems. Switching vendors would necessitate even more extensive testing. He said he would consider jumping to another architecture only if it would deliver a four- or five-to-one performance improvement.

The ability of Sun Fire V490-E25K systems to allow mixed-generation processors was cited as an advantage in facilitating migration to UltraSPARC IV+. Inserting a Uniboard with the new processors into an existing Sun Fire E6900 allowed one customer to create a test domain that closely resembled the production environment running on other Uniboards in the same server. According to that customer: "It is a really huge benefit to be able to divide an existing server and not have to bring in a whole new platform, as some other vendors require." He was able to test his own workload against a section of his database, using a portion of the actual server he planned to upgrade.

Another user of Sun servers acknowledged that there are sometimes reasons to bring in a new server and redeploy the older server to a less performance-critical application. However, he observed that a machine-to-machine workload migration does entail effort and costs. He sees a big advantage with the ability to swap out processor/memory boards to incrementally upgrade existing Sun Fire servers. That incremental upgrade minimizes disruption and the associated migration costs.

A customer with computationally intensive workloads employs racks of small SMP servers. He finds the ability to incrementally add more servers as the workload expands to be an easier budgetary justification than to attempt to predict future workload growth in order to justify obtaining a large SMP. His sweet spot has been a four-chip SMP, until now using single-threaded UltraSPARC processors. With dual-thread UltraSPARC IV+, he could consider reducing the number of rack servers needed to solve the same problem. But for him, "The win comes by being able to double or triple the throughput so I can scale the problem larger or increase the resolution granularity to obtain more accurate results." What he likes is that Sun's low-end midrange servers, such as the Sun Fire V490, contain a set of key RAS characteristics – including remote management capability and redundant hot plug components – that are typically found on enterprise-class systems.

A major independent software developer, well known for its Enterprise Business Intelligence software, obtained an early UltraSPARC IV+ server primarily to validate that various versions of its software would continue to be compatible with Sun's latest platforms. SPARC/Solaris is the largest UNIX environment for this ISV. Therefore, verifying compatibility is a key concern. But, the Product Manager responsible for the validation testing was not worried. He stated: "You can count on Sun. It's just like clock work – if Sun says it's compatible, then it is. And, if there are any problems they will be minor in nature and will be resolved quickly." The testing of UltraSPARC IV+ was even better than he anticipated – no problems were encountered. Since customers use his firm's software in a wide range of environments, he was reluctant to predict the range of performance gains enabled by UltraSPARC IV+. But he said that virtually everyone using his application suite will have some portions of their code that will benefit from the higher performance of UltraSPARC IV+. Individual customers will have different proportions of computationally intensive code and I/O-bound processing, so he did not wish to

make a blanket statement regarding overall gain. Nonetheless, he would recommend that his SPARC/Solaris customers should plan their upgrades to Sun's latest processors.

Without exception, the interviewed beta site customers recommended that other SPARC/Solaris users should move to UltraSPARC IV+. They all agreed that UltraSPARC III users would reap immediate benefits, typically more than doubled throughput thanks to CMT. Those already using UltraSPARC IV with CMT will benefit from the on-chip cache of UltraSPARC IV+, along with other processor design enhancements. However, there was not a consensus regarding the extent of that performance boost, since the gain is application dependent. Nonetheless, some customers felt they saw almost a doubling of performance on some codes. There was complete agreement that the new chip design did preserve software compatibility and that the migration to new hardware did not require code modification.

### **The IDEAS Bottom Line**

Advances in semiconductor fabrication technologies will continue to allow processors to become increasingly powerful. But, processor engineers at all vendors now acknowledge that innovative chip design has become more important than a dependence on ever-faster frequencies. Sun was early to recognize this shift and has responded with CMT implementations, including the enterprise-class UltraSPARC IV+.

Our investigation into the benefits of CMT included interviewing a sample of early users of UltraSPARC IV+. Our analysis concurs with their observations that UltraSPARC IV+ offers the potential for significant performance gains, especially for users with UltraSPARC III or UltraSPARC II systems.

The interviewed customers were unanimous in their view that Sun has preserved binary compatibility and that UltraSPARC IV+ proved to be a non-disruptive upgrade. Painless upgrade has long been a hallmark of Sun's customer focus. We commend Sun for maintaining that commitment to straightforward, non-disruptive upgrades.

IDEAS recommends that customers seeking high-throughput Solaris-based computing should examine how UltraSPARC IV+ can help achieve their goals and should determine how to incorporate Sun's CMT into their environments. Solaris customers with a mixture of operating environments should seriously evaluate expanding their SPARC/Solaris capabilities with a transition to CMT-based platforms. In addition, other UNIX users who recognize the breadth of Solaris-based applications should also consider SPARC/Solaris when mapping out their future plans.

Although the software industry has not yet reached consensus regarding appropriate software licensing methodologies, the advantages of efficient processor implementations, such as Sun's CMT offerings, will clearly position multicore/multithread designs as the preferred processor designs of the future.

## Appendix

The benchmark results listed in the tables below provide supporting details for the charts contained in the body of this paper. The charts and tables primarily illustrate the performance benefit of UltraSPARC IV+ compared to prior UltraSPARC implementations. Comparisons with processor chips from competing server vendors is often difficult because vendors do not always measure the same benchmark test suites.

These results are current as of November 2005. For latest results on industry-standard benchmarks, please refer to: [www.ideasinternational.com/benchmark/bench.html](http://www.ideasinternational.com/benchmark/bench.html).

Table 2. SPECjbb2000 Results for Sun Fire 6800 and Sun Fire E6900

System	Processor GHz	Chips, Java Threads	ops/s	Software	Date
Sun Fire E6900	UltraSPARC IV+ 1.5 GHz	24 48	747,791	Solaris 10 HotSpot 1.5.0	8/05
Sun Fire E6900	UltraSPARC IV 1.2 GHz	24 48	421,773	Solaris 9 HotSpot 1.4.2	1/04
Sun Fire 6800	UltraSPARC III 900 MHz	24 24	174,658	Solaris 8 HotSpot 1.3.1	10/01
Sun Fire 6800	UltraSPARC III 750 MHz	24 24	138,512	Solaris 8 HotSpot 1.3.1	10/01

Table 3. 100 GB TPC-H for Four-Chip Sun Fire V480, V440, V490

System	Processor GHz	Chips, Threads	QpH \$/QpH	Software	Date
Sun Fire V490	UltraSPARC IV+ 1.5 GHz	4 8	6,433.4 \$22.30	Solaris 10 Sybase 12.6	10/05
Sun Fire V480	UltraSPARC III 900 MHz	4 4	1,760.5 \$60.00	Solaris 9 Sybase 12.5	3/03

Table 4. SPECjbb2005 Results for Midrange Servers

System	Processor GHz	Chips, Java Threads	bops	Software	Date
Sun Fire E6900	UltraSPARC IV+ 1.5 GHz	16 32	248,075	Solaris 10 HotSpot 1.5.0	11/05
IBM p5-570	POWER5+ 1.5 GHz	8 32	244,361	AIX 5.3 J2RE 1.5.0	10/05
Sun Fire V890	UltraSPARC IV+ 1.5 GHz	8 16	117,986	Solaris 10 HotSpot 1.5.0	9/05
IBM p5-550Q	POWER5+ 1.5 GHz	4 16	91,806	AIX 5.3 J2RE 1.5.0	9/05
Sun Fire V890	UltraSPARC IV 1.35 GHz	8 16	75,862	Solaris 10 HotSpot 1.5.0	5/05

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