White Paper

SGI® Altix® XE: Addressing the Hidden Costs of Cluster-Based High Performance Computing

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1.0 Achieving Value Across the Cluster Lifecycle

Clusters offer an economical approach to high performance computing (HPC). As such, they have been the main force driving the recent rapid expansion of HPC, with an installation growth rate of approximately 50% per year over the last five years. The ongoing acceleration of higher performance for lower cost is reducing HPC cost-of-entry and helping to bring the benefits of parallel computing to an ever-greater range of applications and organizations. Clusters' inherent modularity means that businesses can start small and build their HPC environments as their need grows.

Clusters have proved so successful in the cost-priority sector of the HPC market that, to a large extent, the marketplace now views them as commodity hardware. This viewpoint has much validity when comparing raw price/performance numbers for cluster hardware offerings across the vendor community. Prices are low, performance is high, and basic server specifications are similar. From a purely hardware standpoint, there just doesn't appear to be that much difference between vendor offerings.

As organizations that have used clusters for some time will attest, however, initial hardware cost represents just a small portion of the total cost of ownership (TCO). The immediate advantage of low cost-of-entry, particularly evident for relatively small installations of just a few servers, can become completely swamped by ancillary costs over time. Several factors, in particular, can lead to high TCO costs:

- System complexity, leading to difficulties in maintenance and scaling
- Data center environmental impact
- Cluster configuration and set-up effort
- Ongoing administration and application development complexities

SGI, the technological leader in HPC, tackles these hidden costs head on with its SGI Altix XE line of cluster solutions. SGI Altix XE clusters provide superior price performance and energy efficiency for mainstream high performance computing, with flexible solutions designed to handle a wide range of application areas, from scientific research and computer-aided engineering (CAE) to finance and digital content creation (DCC). SGI Altix XE clusters combine the powerful Intel® Dual-Core and Quad-Core Xeon® Processor-based architecture with SGI's expertise in designing and delivering some of the most advanced HPC systems available today. The result is breakthrough value, ease-of-use, and no-compromise performance.

In addition to their highly competitive price/performance story, SGI Altix XE clusters offer a number of innovative features and benefits that serve to mitigate overall TCO, particularly for scale-out scenarios:

- Factory integration and testing of the complete cluster solution, for "power-up-and-go" immediate productivity
- Comprehensive and highly configurable software solution stacks, providing best-of-breed management tools and a wide choice of development tools to match your exact requirements. SGI engineers also work closely with independent software vendors (ISVs) to help tune applications for optimal performance.
- Factory-integrated storage solutions
- Power and cooling efficiencies, to further reduce data center costs
- Innovative compact board design, to reduce impact on data center real estate
- Onboard interconnect connections, to reduce the number of network cards, limiting component costs while boosting ease of system scalability
- Access to SGI's world-class Professional Services and Support organizations, offering more than 25 years' experience in designing, implementing, and supporting HPC solutions.

SGI Altix XE clusters bring low TCO to high performance computing. With SGI's innovative total lifecycle approach to product design and support, TCO continues to track low, even as HPC requirements scale over time.

2.0 SGI Altix XE Clusters: Cutting-Edge Solutions at an Affordable Price Point

SGI's Altix XE line of servers and clusters offers exceptional value for high performance computing. The SGI Altix XE product line incorporates the latest in Intel's advanced Dual-Core and Quad-Core Xeon processor architecture into dense and energy-efficient packages, with key hardware and software enhancements from SGI.

2.1 Incorporating Advanced Server Technology

A cluster consists of a set of tightly integrated servers, with at least one head node and multiple compute nodes per cluster. The head node handles overall cluster administration functions. Actual application processing occurs in parallel across the set of compute nodes. Depending on the need of the application, the number of compute nodes in a cluster can range from just a few servers to hundreds or even thousands. SGI Altix XE clusters are easy to scale, enabling users to design a system that meets their specific, current needs, while reserving the potential to scale the system in the future as processing needs grow or change.

Utilizing SGI Altix XE servers for their compute and head nodes, SGI Altix XE clusters provide flexibility in design to meet the needs of a wide range of HPC applications, with value-focused emphasis on performance, density, efficiency, and connectivity. SGI Altix XE servers include advanced features such as a super-fast 1600MHz front-side bus, up to 64GB of memory per compute node, and an ultra-dense architecture that packs up to two eight-core nodes in a slim 1U form factor (Figure 1). They use fully buffered DDR2 memory and support 20GB/second InfiniBand and/or Gigabit Ethernet interconnects. The SGI Altix XE servers are available for purchase as high performing

standalone workgroup servers, but their design is particularly well suited for use as nodes in cluster configurations. SGI Altix XE clusters incorporate the servers in a variety of configurations and performance options.

Figure 1. SGI Altix XE310: Two Nodes on a Single Board

2.2 Spanning the Linux® and Windows® Domains

SGI Altix XE clusters are available with either Linux or Microsoft® Windows Compute Cluster Server 2003 (WCCS) software stacks, to match the needs of the broadest range of environments. The Linux versions of SGI Altix XE clusters feature SGI ProPack™ for Linux, which provides performance and administration features, and additional third-party tools for cluster management, job scheduling, and associated activities. The WCCS version includes a complete integrated cluster solution stack from Microsoft, including Compute Cluster Administrator, Compute Cluster Job Scheduler, and MS-MPI. Additionally, WCCS takes advantage of existing Windows infrastructure tools such as Active Directory®.

SGI Altix XE also offers the option of combining WCCS and Linux on the same cluster, providing maximum flexibility for shops running HPC applications in both Linux and Windows environments. Depending on your application needs, you can either dedicate the entire cluster alternately to Linux or WCCS, or run Linux and WCCS applications simultaneously on separate compute nodes within the cluster.

Two Linux/WCCS cluster combinations are available on SGI Altix XE clusters: dual-boot and “split-brain”. Both options require separate Linux and WCCS head nodes. The difference lies in how the compute nodes are configured. In the dual-boot configuration, each compute node includes both Linux and WCCS, residing on separate partitions. Depending on the cluster’s application load, you can boot some or all compute nodes as WCCS or Linux. When the application load changes, changing the mix of WCCS and Linux compute nodes is a simple matter of rebooting the nodes.

With the split-brain approach, just a single operating system resides on each compute node. You decide when ordering the cluster what combination works best for your application needs. For example, if the majority of your applications run on WCCS, you might choose to configure a 24-compute-node system with 16 WCCS nodes and 8 Linux nodes. The split-brain option is simpler to set up and configure, but it doesn’t offer quite the same degree of flexibility as the dual-boot option. In either case, SGI will deliver SGI Altix XE clusters to your data center pre-loaded with whatever options you require.

2.3 Addressing the Workflow Continuum

For mixed workflow environments, SGI Altix XE clusters can be deployed in combination with SGI® Altix® servers and supercomputers or SGI® Altix® ICE advanced blade servers,

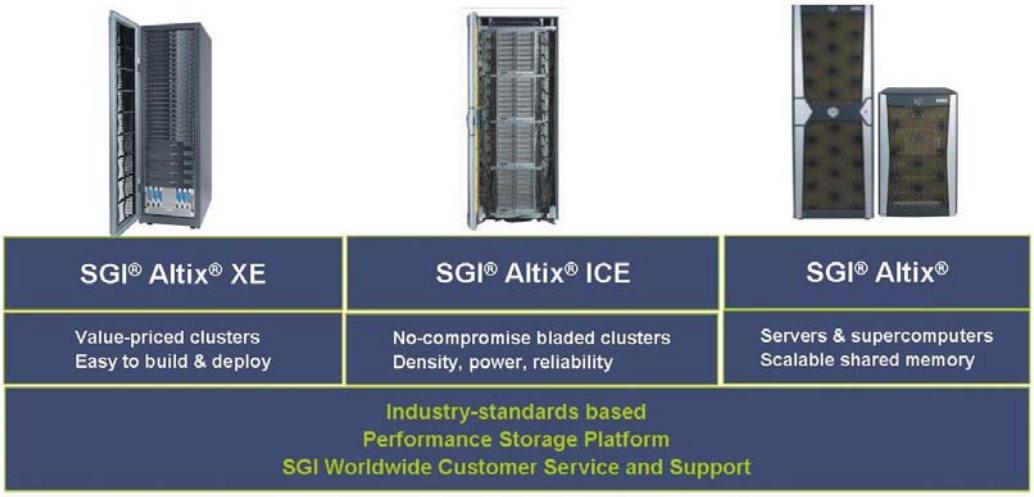

Figure 2. Addressing the High Performance Workflow Continuum

to optimally address diverse processing requirements. This hybrid compute environment offers the best of capacity and capability compute solutions, with an ability to scale up and/or scale out as needed to meet current and future processing needs. SGI Altix XE clusters lead the cost-focused side of the SGI server product line, offering high performance solutions with easy cluster scalability at an attractive price point.

2.4 The SGI Altix XE Line of Clusters and Servers

SGI Altix XE clusters are available in custom configured and factory-built, providing maximum flexibility to handle the diversity of performance computing needs.

The SGI Altix XE1200 cluster configuration uses SGI Altix XE250 compute nodes and offers advanced extensibility, with a rich set of expansion and I/O options to address the broadest range of compute requirements.

The SGI Altix XE1300 cluster configuration, with SGI Altix XE310 or SGI Altix XE320 compute nodes built on an innovative new board design, supports up to 16 processor cores in a 1U blade, delivering industry-leading performance density with cost efficiency.

SGI Altix XE clusters incorporate SGI Altix XE250 head nodes, for maximum extensibility and power.

Table 1 outlines the key features of the SGI Altix XE servers. These servers can be either incorporated into SGI Altix XE clusters as compute and head nodes or configured as standalone workgroup servers.

	Altix XE310	Altix XE320	Altix XE250
Chassis	1U	1U	2U
Processors	Up to four Quad-Core Intel® Xeon® Processors, 5400 Series (2 per node) - Front Side Bus: 1333 MHz - L2 Cache: 12MB	Up to four Dual or Quad-Core Intel® Xeon® Processors, 5200 or 5400 Series (2 per node) • Front Side Bus: 1600 or 1333 MHz • L2 Cache: 6MB for 5200 series, 12MB for 5400 series	Up to two Dual or Quad-Core Intel® Xeon® Processors, 5200 or 5400 Series • Front Side Bus: 1600 or 1333 MHz • L2 Cache: 6MB for 5200 series, 12MB for 5400 series
Internal Storage	Four SATA drive bays (2 per node) Four SAS drives available via optional PCIe card Optional RAID 0, 1		Eight SATA/SAS drive bays 1 x DVD-RW drive RAID 0, 1, 5 (optional), or 10
Memory	64 GB DDR2 800 or 667 MHz FBDIMM memory (32GB per node) Supports memory sparing and mirroring		64 GB DDR2 800 or 667 MHz FBDIMM memory Supports memory sparing and mirroring
Add-in Card Support	2 x PCIe x8 (1 per node)	2 x PCIe x16 (1 per node)	2 x PCIe x8 gen 2 1 x PCIe x8 gen 1 1 x PCIe x4 gen 1 1 x PCI-x 133/100
Benefits	Dense compute node Low-cost	Dense compute node, with enhanced processing capabilities	Powerful cluster head node I/O rich, extensibility, redundancy

Table 1. SGI Altix XE Server Characteristics

3.0 A Complete Factory-Integrated Software Solution Stack – Customized to Match Your Needs

SGI Altix XE clusters run industry-standard operating systems, with a choice of SUSE Linux Enterprise Server, Red Hat Enterprise Linux (RHEL) or Microsoft Windows Compute Cluster Server 2003 (WCCS). Built around these operating systems are complete factory-integrated software stacks, with a wide choice of tools that cover the gamut of the HPC application lifecycle, from application development and cluster management to job submission and performance tuning.

This paper focuses on the Linux-based software solution stacks. For detailed information on the WCCS version of SGI Altix XE, see the SGI white paper, "Extending the High Performance Computing Workflow with SGI Altix XE Clusters Running Microsoft Windows Compute Cluster Server 2003", available at www.sgi.com.

SGI is an active partner in the Intel Cluster Ready program, and SGI Altix XE is certified as Intel Cluster Ready. This means that SGI Altix XE conforms to key cluster standardization criteria and ensures that all ISV applications certified as Intel Cluster Ready will run on SGI Altix XE clusters.

3.1 Linux Leadership in HPC

SGI offers a comprehensive Linux-based software stack, with a wide variety of tools to choose from, ensuring a perfect match with each customer's application needs. These tools range from the SGI ProPack optimization suite to a full spectrum of ISV and open source tools and libraries. SGI integrates, configures, and tests the entire software stack on the cluster, before delivering the complete product to the customer with power-up-and-go functionality.

SGI's leadership role within the Linux community is unmatched in the industry. The company is a major and long-standing contributor to the Linux standard. With a solid strategic focus on Linux, SGI has built an in-house engineering and support team with Linux expertise that is unmatched in the industry. SGI engineering teams collaborate closely with partners like Intel and Novell, to ensure the greatest possible levels of optimization for its software stacks. In addition, the SGI Professional Services and Support teams have deep and extensive experience covering all aspects of Linux, with the expertise to resolve kernel-level issues quickly and efficiently.

3.2 SGI ProPack – Enriching the Linux Environment

Supplementing the Linux operating system, SGI offers the optional SGI ProPack for Linux, with features to drive performance and simplify system administration. SGI ProPack includes a powerful and cost-effective set of enhancement tools, designed to ensure that SGI Altix XE users become productive immediately. These tools include linkless FFIO to accelerate I/O calls, resulting in dramatic performance enhancement for I/O intensive applications. Table 2 enumerates some key features of SGI ProPack.

Linkless FFIO	Accelerates I/O calls. Drives dramatic performance enhancement in I/O-intensive cluster configurations.
CPUSETS	Used directly by cluster workload manager. Provides ability to allocate specific CPU for system daemons, etc., for improved performance, decreased CPU contention.
ESP	Administrator tool for monitoring system health.
XVM	Provides disk striping, mirroring – makes nodes CXFS-ready. (Not available under RHEL, because RHEL does not support XFS.)
NUMATOOLS	Used to specify CPU, memory characteristics & fine-tuning – accessible by developers, users to tune application execution.
Performance Co-Pilot™	System monitoring tool; used to view processor activity, loads, etc.
SGI MPT (Message Passing Toolkit)	SGI's MPI library toolkit, optimized for Altix XE.
Storage Administration Tools	Additional tools for managing disk resources – xscsi, udev, LSI commands.
Failover/Cluster Manager	Tool for cluster failover management.

Table 2. SGI ProPack for Linux

3.3 Cluster Development Tools

SGI Altix XE works with a broad selection of development tools and applications available from Intel, a variety of ISVs, and the open source Linux community. SGI can bundle these tools with its SGI Altix XE clusters, delivering a factory-integrated and tested solution directly to the customer.

Among the programming languages available for SGI Altix XE development are C++ and Fortran (with compilers and debuggers from Intel and GNU) and Java2 (from the Linux distribution). A variety of libraries, including math, threading, and multimedia function libraries, are also available from Intel and other vendors. Analysis tools include the Intel VTune™ Performance Analyzer for Linux and the Intel Cluster Toolkit, featuring the Intel Trace Analyzer and Collector. The Cluster Toolkit also includes the Intel MPI Library and the Intel Math Kernel Library (MKL).

The MPI options for SGI Altix XE are particularly rich, exemplifying SGI's philosophy of offering a breadth of solutions so as to match customers' needs exactly. MPI stands for Message Passing Interface, the key standards-based library for providing parallel processing functionality. SGI offers three categories of options for MPI on SGI Altix XE:

- SGI MPT – the SGI Message Passing Toolkit, optimized for SGI's Altix and Altix XE systems and included in SGI ProPack.
- Commercially available MPI libraries, from companies like Intel, Voltaire, and Scali – for multi-platform compatibility, along with competitive performance.
- Open source MPI libraries, such as OpenMPI and MVAPICH-2 – available free for organizations needing the flexibility to modify source code to derive optimal application-specific performance.

3.4 Bundled Management Tools

SGI bundles industry-leading management tools as optional software stack components. Two tools are of particular importance for the cluster lifecycle: Scali Manage™ and Altair® PBS Professional™.

Scali Manage provides total cluster lifecycle management. It provisions, manages, and maintains clusters, grids of clusters, and server farms. It accelerates cluster deployment, delivers image- and package-based provisioning, and simplifies cluster lifecycle management. Scali Manage comes with comprehensive tools for system installation, configuration, management, and monitoring.

Altair PBS Professional is a workload management software platform for cluster and grid computing, offering robust, flexible, and scalable workload management. It helps reduce costs by maximizing hardware utilization while managing software licenses more effectively. PBS Professional reduces system administration costs as well by simplifying user access and improving precision of usage reports. It improves reliability and availability with features such as server software failover, automatic detection of system failures, and automated rescheduling of disrupted jobs.

3.5 SGI Altix XE Software Stack

Table 3 summarizes the key components of SGI Altix XE software solution stack. Depending on your specific needs, SGI can bundle these or other components with SGI Altix XE.

4.0 Factory-Integrated Storage Solutions

The SGI® InfiniteStorage product line offers a full range of NAS and SAN storage solutions. With its commitment to power-up-and-go functionality, SGI will deliver your SGI Altix XE cluster fully integrated with cluster with an integrated storage solution. SGI's factory-integration service extends beyond its InfiniteStorage product line to third-party products as well, if they suit your storage needs better.

The SGI® InfiniteStorage NEXIS NAS family of storage solutions offer the latest advances in scalability and ease-of-use for HPC applications. With scalable investment protection, reduced manageability costs, and high performance, NEXIS represents an ideal storage platform for SGI Altix XE cluster systems.

Operating System	Novell SUSE Linux Enterprise Server or Red Hat Enterprise Linux
Performance Optimization	SGI ProPack
Cluster Management	Scali Manage
Workload Manager	Altair PBS Professional
MPI	Multiple options available, including SGI MPT, Intel MPI Library, Scali MPIConnect, MVAPICH-2, and OpenMPI.
IB Fabric Management	Gridstack™ or SGI InfiniBand Fabric Manager (based on OFED)
Development Tools	Intel C++ and Intel Fortran compilers, Intel VTune, Intel Math Kernel Library, Intel Trace Analyzer and Collector, Intel Thread Checker, and more.

Table 3. SGI Altix XE Linux-Based Software Solution Stack

The product line ranges from the NEXIS 500, with a maximum storage capacity of 3.75TB, to the NEXIS 7000, with up to 168TB of mid-tier-performance or 67TB of high-performance capacity. For SGI Altix XE cluster systems, two offerings, in particular, stand out:

- **SGI InfiniteStorage NEXIS 500** – for smaller-sized clusters. The NEXIS 500 provides a maximum of 3.75TB of storage, with up to 5 SATA drives in a single 2U chassis.
- **SGI InfiniteStorage NEXIS 2000** – available in SAS or SATA versions. The NEXIS 2000 SAS offers high-performance storage for application areas such as media, education, CAE, and scientific research, utilizing dual RAID controllers and providing a maximum of 43TB of high-performance storage capacity with up to 144 drives. The NEXIS 2000 SATA is ideal for online archives and back-up, utilizing a single RAID controller and providing up to 108TB storage capacity with a maximum of 144 drives.

While NEXIS 500 and NEXIS 2000 are targeted to meeting the needs of most SGI Altix XE applications, higher capacity NEXIS products are also available to meet the needs of even the most demanding applications.

All NEXIS products ship with the browser-based InfiniteStorage Appliance Manager, thus ensuring a consistent, single management interface across the entire product family. The Appliance Manager features automated storage asset discovery and configuration guidance for fast and easy initial deployment and future storage capacity expansion. Granular-resolution guidance and storage-utilization tools help reduce management costs and maximize storage efficiencies. With its ease-of-use, comprehensive functionality, and scalability, the Appliance Manager ensures low TCO for SGI Altix XE storage solutions.

In addition to the integrated InfiniteStorage Appliance Manager, SGI offers numerous other software tools, both proprietary and third-party, to handle storage-related tasks such as data migration, backup and recovery, and resource management.

For I/O intensive cluster applications, such as post-production digital content creation, SAN is sometimes more appropriate than NAS storage. SGI offers a full range of SAN solutions to choose from. Complete with 4Gb/second SAN infrastructure and the performance-leading SGI InfiniteStorage Shared Filesystem CXFS™, SGI SAN Servers provide instant data sharing – eliminating data access bottlenecks – and provide a single, centralized filesystem to ease administration and access, as well as a single point of backup.

SGI offers an entire portfolio of storage solutions, featuring its own hardware and software products as well as those from third-party vendors, to meet customers' exact needs. With customized factory integration and testing, spanning both SGI Altix XE clusters and storage appliances, SGI delivers an optimized power-up-and-go cluster infrastructure that ensures quick deployment and immediate productivity.

5.0 Handling the Wide-Ranging Variety of HPC Application Needs

SGI Altix XE represents a cost-effective, highly manageable solution for any application area that depends on fast processing of large quantities of complex, parallel computations. The SGI Professional Services organization offers deep and long-standing expertise in a wide range of HPC application domains, including CAE, digital content creation, financial services, and the sciences. SGI's experience in these markets is bolstered by its close collaboration with key ISVs.

6.0 SGI Altix XE Clusters Deliver Unbeatable TCO

With SGI Altix XE, SGI maintains its leadership in offering performance with value. SGI Altix XE cluster solutions meet the needs of a wide range of high performance computing requirements with the latest design innovations – at an unbeatable value point, in both initial and long-term costs.

6.1 Factory Integration for Immediate, Painless Deployment

SGI is renowned for delivering products with power-up-and-go factory integration and testing, ensuring immediate customer productivity and easing the IT burden. SGI's experience in factory integration extends beyond standard cluster configurations to encompass storage integration as well as custom software integration. SGI Altix XE clusters arrive at the customer's site fully integrated, tested, and ready-to-go.

6.2 Simplified Manageability

SGI factory integration means that you can immediately manage the SGI Altix XE cluster as a single unit, rather than starting from a set of building-block servers requiring significant expenditure in time and effort to integrate and prepare for use. SGI Altix XE's comprehensive software solution stack includes all the tools you need to manage your clusters optimally. And, with enhanced compute density and onboard InfiniBand and Gigabit Ethernet, the design of SGI Altix XE1300 reduces the number of components and thus the complexity of managing and scaling cluster hardware.

6.3 Reduced Data Center Costs

SGI Altix XE clusters leverage your investment in data center infrastructure by reducing costs on several levels: space, power, and cooling. The compact SGI Altix XE310 and SGI Altix XE320 board design, packing up to 16 core nodes in a 1U form factor, achieves a level of performance density that ensures efficient use of precious data center real estate. This unique design also serves to significantly reduce power costs, with systems that use a single, steamlined 980W output power supply that is 88% efficient, realizing a low per node power loss of approximately 67W.

SGI also brings its unmatched prowess with cooling technologies to SGI Altix XE clusters. Larger installations of SGI Altix XE clusters are available with SGI-designed racks incorporating water-chilled doors. This third-generation cooling technology, developed originally for the SGI Altix line of servers and supercomputers, represents the state-of-the-art in server cooling. With the water-cooled option, even a fully populated rack of SGI Altix XE servers has minimal effect on ambient data center temperature, with up to 95% of rack heat dissipated to chilled water. The water-cooled option also provides significant power savings in comparison to cooling. While actual performance depends on many site and geographic variables, the water-cooled option can significantly reduce cooling equipment power consumption. The combined electrical operating cost for an SGI Altix XE cluster and its associated cooling equipment can be reduced by 17% or more. Use of the water-cooled option also increases overall system reliability by mitigating the common problems of hot-aisle/cold-aisle recirculation and hot spots with the data center.

6.4 An Advanced HPC Development Environment

The power, flexibility, and scalability of SGI Altix XE enables customers to design cluster systems that exactly meet current processing needs, while maintaining the ability to adjust and scale for future applications. A configurable software solution stack provides a comprehensive and optimized set of tools to handle the needs of the entire application lifecycle. Complete factory integration means that SGI Altix XE clusters arrive at the customer side ready for immediate deployment. And SGI's industry-leading Professional Services and Support organizations, with deep technology and industry experience, are always ready to provide the expertise to meet any processing challenge.

As an active member of the "Intel Cluster Ready" program, SGI works with Intel to ensure that the SGI Altix XE platform meets the Intel® Cluster Ready Specification. Because SGI Altix XE is "Intel Cluster Ready" certified, applications that have also been certified through the program have been fully tested and qualified to run on the SGI Altix XE platform. With this certification, customers can be assured that the applications that they plan to deploy on their SGI Altix XE cluster are "ready to go", saving valuable time and resources.

6.5 The Bottom Line: High Performance with Low Total Cost of Ownership

Low TCO starts with initial server cost, and SGI Altix XE delivers compute-dense configurations with industry-leading price/performance value. SGI Altix XE extends that value through technological innovations on a number of fronts:

- Full factory integration and testing – encompassing cluster hardware, software, and storage
- A comprehensive, customizable software solution stack
- Scalable integrated storage solutions
- Power, cooling, and space efficiencies
- Innovative use of onboard interconnect
- Industry-leading Professional Services and Support teams

The SGI Altix XE cluster platform, embodying SGI's reputation for innovation in high performance computing, delivers solutions that are easy to deploy and scale while providing price/performance value throughout the system lifecycle.

7.0 About SGI

SGI is a leader in high-performance computing, with over 25 years of experience in solving the most demanding compute and data-intensive problems. SGI delivers a complete range of high-performance server and storage solutions along with industry-leading Professional Services and Support, enabling its customers to overcome the challenges of complex data-intensive workflows and accelerate breakthrough discoveries, innovation, and information transformation.

SGI has long been renowned for offering best-of-breed solutions in the Linux HPC market. With the addition of Microsoft® Windows Compute Cluster Server 2003 to its line of SGI Altix XE cluster solutions, SGI now delivers the same powerful and cost-effective HPC clusters to businesses with Windows-based IT investments.

SGI helps customers solve their computing challenges, whether it's enhancing the quality of life through drug research, designing and manufacturing safer and more efficient cars and airplanes, studying global climate, providing technologies for homeland security and defense, or helping enterprises manage large quantities of data. With offices worldwide, the company is headquartered in Sunnyvale, California, and can be found on the Web at www.sgi.com.

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