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Oracle Solaris and Oracle SPARC Servers—Integrated and Optimized for Mission Critical Computing

ORACLE

Executive Overview

This document is intended for IT architects, system administrators, and developers that want to understand the details of how Oracle® Solaris and SPARC® servers can improve your application solution environment. This paper will provide technical information on how Oracle Solaris and the SPARC processor have been highly optimized for each other, improving throughput, security, and resiliency throughout the application solution stack, driving maximum ROI and minimum TCO. It includes brief technical descriptions of how specific Oracle Solaris features and capabilities are implemented in a system-wide approach to optimize the specific functionality of the SPARC processor family in the areas of scalable performance, advanced reliability, security, and cost-effective virtualization—and enhance your Oracle solution set.

Introduction—Oracle Datacenter Integration

Oracle offers customers a complete integrated stack, from the applications layer at the top to disk storage systems at the bottom, as shown in Figure 1. Oracle is the number one vendor in the top three software segments (applications, middleware, and database), and Oracle Solaris is today the number one deployment platform for Oracle Database applications in the market. Oracle offers customers a complete top-to-bottom solution that is open and fully integrated.

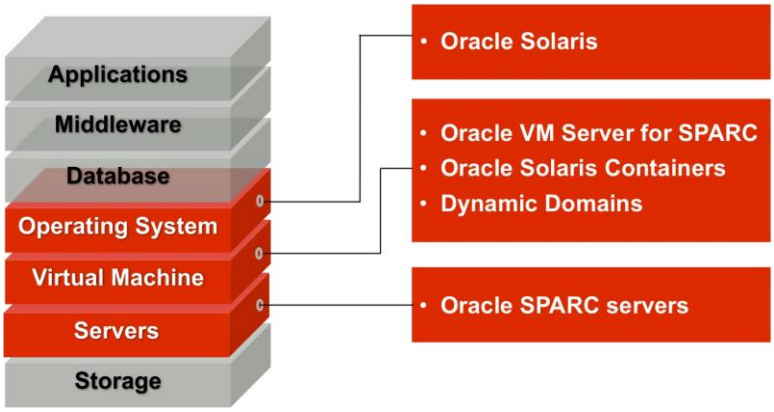

Figure 1: Complete. Open. Integrated. Oracle Solaris and Oracle's SPARC servers are the optimal solution stack for Oracle Database and Applications.

Oracle has a long history of optimizing the platforms for scalability, reliability, and security. These improvements have enhanced and optimized the entire stack and leveraged innovation throughout. This paper offers a high-level discussion of the benefits of Oracle Solaris running on Oracle's SPARC T-Series and Sun SPARC Enterprise M-Series servers, and drill-down information on specific optimizations and advantages for increased reliability, scalability, security, and virtualization. Resources that can provide more information are listed at the end of the paper.

Here are some examples of how cooperative innovation improved the application performance and reliability on Oracle Solaris, SPARC servers, and Oracle Database and Applications.

Scalability and Performance

- Solaris was one of the first commercially available UNIX® to offer a 64-bit version. This enabled the 64-bit version of Oracle 8*i* to scale to beyond the 4 GB memory barrier. This was necessary to make use of the 64 GB of memory available on the Sun Enterprise 10000 ("Starfire") servers.
- Large page support and multiple page size support (MPSS) expanded memory page sizes up to 256 MB, and increased the performance of Oracle's SPARC T-Series and Sun SPARC Enterprise M-Series servers running Oracle Database.
- Memory Placement Optimization (MPO) enables processors to have an affinity for the closest memory on Non-uniform Memory Access (NUMA) systems—the types of multisocket, large memory systems that are powered by SPARC processors and Oracle Solaris. Sun collaborated with Oracle to define and use the `lgroup` API, `lgrp_init` (`3LGRP`), and enable Oracle to optimize local versus remote access to the System Global Area (SGA, the database buffer cache) on NUMA machines. These optimizations were made default on Oracle 10*g* running on Oracle NUMA based servers. These optimizations help increase the locality of reference for the SGA and Process Global Area (PGA, a dedicated memory cache). The performance improvements can be quite drastic depending on the server. Oracle Solaris MPO innovations are key to scaling on servers with high NUMA ratios.
- Intimate shared memory (ISM) shares translation tables involved in the virtual to physical address translation for shared memory pages, as opposed to just sharing the actual physical memory pages. ISM was a critical technology which enabled Oracle to efficiently scale on large SMP systems as well as smaller machines.

Availability

- Dynamic ISM enabled Oracle support for the dynamic SGA feature introduced in Oracle9*i*. This allowed a DBA to dynamically increase or decrease the size of the SGA (up to a limit defined by `sga_max_size`) without needing to restart the Oracle instance. Using the Oracle Solaris Reconfiguration Coordination Manager (RCM), it is also possible to write a script that allows Oracle Database to be alerted when new CPUs/memory are to be removed from the domain, so that the SGA can be dynamically scaled back to allow the board to be removed without shutting down the database.
- For many years Oracle Solaris Cluster software has been evolving to complement and integrate with Oracle Database solutions including Oracle Real Application Clusters (RAC). The result is thoroughly tested, tightly integrated, end-to-end solutions that extend the advantages of Oracle Solaris and Oracle SPARC systems into multiserver, high-availability environments.

Security

Role-based access control (RBAC) is a feature of Oracle Database, Oracle E-Business Suite, and Oracle Solaris. In the RBAC model in Oracle Solaris, users log in as themselves and assume roles that enable them to run restricted administration graphical tools and commands. RBAC is considered a best practice across all Oracle products.

While there are many integration synergies to come, today Oracle offers end-to-end management for the complete hardware software stack, from application to disk. Oracle Enterprise Manager offers customers visibility into underlying Oracle servers, Oracle Solaris and associated virtualization, helping them to resolve issues that could impact application, middleware and database service levels. This includes extensive capabilities for managing physical and virtual Sun environments.

Overview

Oracle Solaris is the centerpiece on which Oracle delivers integrated hardware and software solutions that are reliable, scalable, and secure. Thousands of customers worldwide depend on SPARC-based systems and Oracle Solaris to run their business, usually for one simple reason: these platforms simply don't quit. Maximum scalability is achieved when multicore servers and highly threaded operating systems host middleware and applications that are tuned to take advantage of these capabilities. Servers built using SPARC processors offer up to 512 hardware processing threads and four terabytes (4 TB) of memory. Oracle Solaris offers an industry-leading threading model, the result of nearly two decades of innovation. Oracle Database and Middleware products have been tuned to maximize performance and scalability on this platform. Oracle Solaris offers an exceptionally secure environment, including on-chip encryption capabilities, a robust cryptographic framework, Trusted Extensions, and virtualization capabilities. Finally, a comprehensive development platform enables organizations to create new applications that maximize solution performance while improving reliability.

The Oracle Solaris Ecosystem

Oracle's comprehensive portfolio of operating system, virtualization, and cluster technologies includes Oracle Solaris, Oracle VM, Oracle Solaris Cluster, and the Oracle Solaris Studio software development tools, which form the core of a large developer ecosystem.

Oracle Solaris is a proven, industry-leading operating system with features designed to handle enterprise, business-critical operations. In fact, Oracle Solaris 10 provides key functionality for virtualization, optimal utilization, high availability, unparalleled security, and extreme performance for both vertically and horizontally scaled environments. Oracle Solaris 10 runs on a broad range of SPARC (and x86-based) systems and compatibility with existing applications is guaranteed. This is why there are over 50,000 businesses and institutions running over 11,000 certified applications on Oracle Solaris today.

Powering Oracle's SPARC servers, Oracle Solaris continues to set world records for performance, scalability, and cost-effectiveness. Oracle is investing more in Solaris than Sun did prior to the acquisition, and will continue to develop innovative technologies and enhance Oracle Solaris.

Oracle Solaris includes many unique and innovative technologies that are uncommon to other operating system vendors—including: Oracle Solaris ZFS, Oracle Solaris DTrace, Predictive Self Healing, built-in virtualization, independent security verification, binary compatibility, and the Oracle Solaris Cluster high availability and disaster recovery solutions. Oracle protects your IT investments by guaranteeing that existing Oracle Solaris 8 and 9 applications will run unmodified on Oracle Solaris 10. As enterprise system hardware often has a service life of 8-10 years (or more), it is comforting to understand Oracle's commitment to providing a long-lived platform for the software environment.

SPARC Processors

SPARC (*S*calable *P*rocessor *ARC*hitecture) is a RISC instruction set architecture developed by Sun Microsystems (now Oracle). The "Scalable" in SPARC comes from the fact that the SPARC specification allows implementations to scale from embedded processors up through large server processors, all sharing the same (non-privileged) core instruction set. A single version of Oracle Solaris runs across Oracle's SPARC systems, including Sun SPARC Enterprise M-Series and Oracle's SPARC T-Series servers. This means datacenters can run a single OS—Oracle Solaris—across all systems, including x86-based systems, from the smallest to the largest, greatly simplifying administration. Combined with Oracle Solaris, Oracle SPARC servers provide record-setting performance, extreme scalability, mainframe-class reliability and availability, and strong security.

Table 1 provides and overview of the key features of the SPARC processor architectures.

TABLE 1: KEY FEATURES OF THE SPARC PROCESSOR ARCHITECTURE BY FAMILY

FEATURE	T-Series with SPARC T3	M-Series with SPARC64 VII
Cores/Threads/Sockets	Up to 16 cores/8 threads/4 sockets Up to 512 processing threads Chip Multithreading (CMT)	4 cores/2 threads/64 sockets Up to 512 processing threads Simultaneous Multithreading (SMT)
Maximum frequency	1.65 GHz	2.88 GHz
L2 cache	6 MB on chip	6 MB on chip
On-chip support	PCI Express bridge, integrated dual 10GbE networking with XAUI, crypto acceleration, L1 and L2 cache, integer execution units, PCIe Gen 2 (x8), hypervisor	L2 cache
Maximum memory (per system)	512 GB	4 TB
Reliability features	Predictive Self Healing, hot-swap components, ECC everywhere, redundant components and networking, hot plugging of PCIe, USB, and SCSI devices.	End-to-end ECC protection; guaranteed data path integrity; automatic recovery with instruction retry; total SRAM and register protection; ECC and Extended ECC protection for memory, memory mirroring, and Predictive Self Healing; full hardware redundancy; fault-isolated dynamic domains; dynamic reconfiguration; hot-plugging,

		autodiagnosis, and recovery; guaranteed data path integrity, total SRAM and register protection.
Security	Multiple on-chip cryptographic capabilities, plus additional protections	Available add-in crypto-accelerator cards
Virtualization (V12N) Included at no extra charge—third-party products also available	Oracle VM Server for SPARC (previously called Logical Domains or LDOMs) and Oracle Solaris Containers	Dynamic Domains and Oracle Solaris Containers
Target environments	Network-facing: consolidation and virtualization, Web, Media, security, OLTP, middleware/SOA, batch processing, datamart, application servers	Data-facing: Optimized for 24x7 mission-critical computing: DSS, ERP, CRM, BIDW, large databases, large-scale OLTP, and HPC/scientific/engineering applications, that require mission-critical RAS features.

As shown in Table 1, the SPARC processor family is designed and optimized for different types of application environments. The same Oracle Solaris provides commonality across both hardware platforms in myriad of applications and different datacenter tiers. The SPARC processor family spans a wide range of enterprise servers to create architectures that are suitable for best efficiency and security, such as with the T-Series, to massive scalability and availability, such as the M-Series. These two platforms create a potent mix of solutions such as CRM systems, and Java™ and Web middleware infrastructure with the T-Series to ERP systems and backend OLTP/DW systems with the M-Series.

SPARC processors provide a range of systems—one to four sockets for T-Series, up to 64 sockets for M-Series—to run critical systems for the business from the edge of the network to deep in the datacenter. Server choice in a solution architecture is based purely on specific application scenarios and expectations, and can be mixed and matched.

A specific recommendation is out of the scope of this paper and we encourage you to understand the SPARC server application scenarios and case studies on Oracle.com or by discussing with your Oracle representative. The exact sizing and capacity planning can be undertaken with the help of Oracle's experts. Your specific scenarios can be tried and tested at Oracle facilities before deployment. The following section describes the specific SPARC servers.

Oracle SPARC T-Series Servers with Chip Multithreading (CMT)

UltraSPARC T2 and SPARC T3 processors power the Oracle SPARC T-Series servers. With support for up to 16 cores/8 threads per core (128 threads per chip)—and up to four sockets—this processor provides breakthrough performance and energy efficiency. In addition, the SPARC T3 processor integrates 10 Gb Ethernet, PCI Express I/O, hypervisor, and cryptographic acceleration directly onto the processor chip. Combined with Oracle Solaris, this approach provides leading levels of performance and scalability with extremely high levels of efficiency. The SPARC T-Series architecture

is ultimately very flexible, and working with Oracle Solaris allows different modular combinations of processors, cores, and integrated components, which offer:

- Increasing computational capabilities to meet the growing demand from Web applications
- Supporting larger and more diverse workloads with greater floating point performance
- Powering faster networking to serve new network-intensive content
- Providing end-to-end datacenter encryption
- Increasing service levels and reducing downtime
- Improving datacenter capacities while reducing costs

Closely orchestrated with Oracle Solaris, these systems provide record-setting performance and excellent RAS characteristics, ideal for maximizing the uptime and ROI of mission-critical enterprise applications. Note that there are additional features that contribute to enhanced reliability, including advanced integration—significantly lower parts component count—and superior energy efficiency that contributes to a reduction of faults due to thermal conditions.

Oracle's SPARC servers running Oracle Solaris are built to achieve high levels of uptime and fast recovery from failures. Administrators can utilize Oracle Solaris commands to remove and replace disks, power supplies, I/O cards, and fan units while the system continues to operate. Two PCI Express root complexes per processor combined with the ability to configure multiple CPUs, memory (DDR3 on T3-Series), and I/O cards add to the resiliency of Oracle's SPARC T-Series servers. Hot-swap and hot-plug chassis-mounted hard drives, fan units, and power supplies improve serviceability and availability.

Sun SPARC Enterprise M-Series Servers with SPARC64 VII

SPARC64 VII processors power Sun SPARC Enterprise M-Series servers. Running Oracle Solaris, these platforms offer mainframe-class features and sustainable levels of record-setting application performance. SPARC64 VII processors provide four cores, with two strands (threads) per core. In combination with Oracle Solaris, SPARC64 VII processors provide simultaneous multithreading (SMT) scalability to support parallel execution of all eight threads across all available processors (from 1–64 processors). Sun SPARC Enterprise M-Series servers feature memory subsystems as large as 4 TB, and high-throughput I/O architectures.

Sun SPARC Enterprise M-Series servers running Oracle Solaris delivers a mainframe-class system architecture for high availability (HA) running Oracle Solaris 10. Furthermore, the range of compute power offered by these servers provides the levels of vertical scalability required for server consolidation and many other deployment classes. Sun SPARC Enterprise M4000 and M5000 servers fulfill mid-range system requirements, while Sun SPARC Enterprise M8000 and M9000 servers deliver the massive processing power needed for high-end computing.

Many design features of Sun SPARC Enterprise M-Series servers work together with Oracle Solaris in contributing to a comprehensive and integrated architectural approach that is designed for high availability of key systems at lower total costs. Mainframe-class RAS features come standard in the Sun

SPARC Enterprise M-Series servers, including automatic recovery with instruction retry, up to 4 TB of system memory with extended error-correcting code (ECC) protection, guaranteed data-path integrity, total static random access memory (SRAM) and register protection, configurable memory mirroring, and many more.

What's more, most major system components are redundant and hot swappable, for increased availability and serviceability. This includes processors, memory, disk drives, I/O cards, power supplies, and more. The Sun SPARC Enterprise M8000 and M9000 servers add the ability to hot-swap CPUs, memory, and the service processors. These systems are able to recover from most hardware failures, often with no impact to users or system functionality. Sun SPARC Enterprise M4000, M5000, M8000, and M9000 servers can recover quickly from many component failures, including serious faults such as the failure of a CPU or a critical ASIC. In fact, no single hardware component failure prohibits Sun SPARC Enterprise M9000 servers from booting.

These innovative CPU designs help Sun SPARC Enterprise M-Series servers offer better performance than competing systems. At the same time, these servers offer full binary compatibility and complete investment protection for owners of previous generations of Oracle and Sun systems.

Architected for Reliability

"Our Sun SPARC Enterprise M-Series servers, combined with Solaris OS and Oracle database, offers rock-solid reliability and uptime along with unmatched investment protection and scalability. We reduced our response time per database transaction by 98.6%, a 72x performance boost, and achieved a positive ROI in three months."

— Bill Dougherty, Director of Site Operations, StubHub

Oracle Solaris is designed for reliability. Built with a small, compact kernel, Oracle Solaris limits the potential for operating system faults and subsequent platform downtime. In addition, Oracle Solaris establishes a clear distinction between the kernel, shared libraries, and applications in order to limit the impact of application failures. Furthermore, the ability to install most patches and other incremental software updates for Oracle Solaris without taking the system offline helps organizations increase uptime and eases serviceability.

There are many complementary features built into Oracle Solaris, Sun SPARC Enterprise M-Series and SPARC T-Series processors and servers, and Oracle Solaris Cluster that promote mainframe-class reliability. On all Oracle SPARC systems, Oracle Solaris Predictive Self Healing and Oracle Solaris Cluster enhance reliability. On Sun SPARC Enterprise M-Series servers, Dynamic Domains (discussed in the Virtualization section) further improves uptime and availability.

Oracle Solaris Predictive Self Healing

Oracle Solaris Predictive Self Healing software proactively monitors and manages system components to help organizations achieve maximum availability of IT services. Predictive Self Healing is an innovative capability in Oracle Solaris 10 that automatically diagnoses, isolates, and recovers from

many hardware and application faults. This enables business-critical applications and essential system services to continue uninterrupted in the event of software failures, major hardware component failures, and even misconfigured software. The Oracle Solaris Fault Manager Architecture (FMA) and Oracle Solaris Service Manager Facility (SMF) are the two main components of Predictive Self Healing.

The FMA, a common system that works across platforms running Oracle Solaris, reduces complexity by automatically diagnosing faults in the system and initiating self healing actions to help prevent service interruptions. This software helps increase availability by configuring problem components out of a system before a failure occurs—and in the event of a failure, this feature initiates automatic recovery and application re-start using SMF. The FMA diagnosis engine produces a fault diagnosis once discernible patterns are observed from a stream of incoming errors. Following diagnosis, FMA provides fault information to agents that know how to respond to specific faults.

The FMA offers comprehensive reliability and availability capabilities on all Oracle SPARC systems. For example:

- CPU "offlining" takes cores and threads (strands) deemed faulty offline. They are recorded and remain offline on reboot until the faulty processor has been replaced, at which point they are made available again.
- Memory page retirement retires pages of memory marked as faulty. They are recorded and remain offline on reboot until the faulty memory has been replaced, at which point it is made available again.

In addition, Sun SPARC Enterprise M-Series servers running Oracle Solaris also provide FMA support on their service processors, or eXtended System Control Facility (XSCF). This allows the XSCF to report faults in the system even if there are no domains running. The alerts are in exactly the same format as the reports from FMA running in a domain.

The SMF facility creates a standardized control mechanism for application services by turning them into first-class objects that administrators can observe and manage in a uniform way. These services can then be automatically restarted if they are accidentally terminated by an administrator, if they are aborted as the result of a software programming error, or if they are interrupted by an underlying hardware problem. Specifically, SMF enables administrators to do the following tasks easily and efficiently with Oracle SPARC servers running Oracle Solaris:

- Observe and manage system-wide services
- Identify "misbehaved" or failed services
- Securely delegate administrative tasks to non-root users
- Automatically restart failed services in the appropriate order of dependency
- Persist the enable/disable of services across system upgrades and patches
- Preserve compatibility with legacy services
- Automatically configure snapshots for backup, restore, undo

- Provide consistent configuration handling

Predictive Self Healing offers comprehensive reliability and availability capabilities on all Oracle SPARC systems.

Oracle Solaris Memory Page Retirement

As a part of the Oracle Solaris Predictive Self Healing technology framework, the Oracle Solaris memory page retirement (MPR) capability works to isolate memory issues without system interruption. Fault Manager examines hardware on a continual basis, notifying the MPR subsystem of pages in need of retirement. MPR retires memory pages containing correctable errors and relocatable clean pages containing uncorrectable errors without interrupting user applications. In addition, MPR can also isolate relocatable dirty pages containing uncorrectable errors, limiting impact on affected user processes and avoiding a forced outage of an entire system. By utilizing MPR on SPARC servers, system interruption rates can be reduced by as much as 35-40 percent[1].

Highly Reliable Memory Subsystems

Oracle Solaris and Oracle SPARC servers work together to ensure the reliability of system memory. Some Sun SPARC Enterprise M-Series servers offer the following:

- **Memory patrol.** Memory patrol periodically scans memory for errors, proactively preventing the use of faulty areas of memory before they can cause system or application errors, improving system reliability.
- **Memory Extended ECC.** The memory extended ECC function of these servers enables single-bit error correction, enabling processing to continue despite events such as burst read errors that are sometimes caused by memory device failures.
- **Memory mirroring.** Memory mirroring on the Sun SPARC Enterprise M4000 to M9000 is an optional, high-availability feature appropriate for execution of applications with the most stringent availability requirements. Memory mirroring duplicates the data on write and compares the data on read to each side of the memory mirror. In the event that errors occur at the bus or dual inline memory module (DIMM) level, normal data processing continues through the other memory bus and alternate DIMM set.

[1] Assessment of the Effect of Memory Page Retirement on System RAS Against Hardware Faults

Oracle Solaris ZFS for Reliable Data

"Solaris provides a couple of key advantages over any other OS. One is just the base reliability of the operating system with storage, things like retrying I/Os. But on top of that there are two key technologies that, frankly, you can't get anywhere else… That's MPxIO for multipath I/O and the other is ZFS."

— Jason Williams, CIO, DigiTAR

Oracle Solaris ZFS technology offers a dramatic advancement in data management with a virtual storage pool design, integrated volume manager, and data services that provide an innovative approach to data integrity.

ZFS software enables more efficient and optimized use of storage devices, while dramatically increasing reliability and scalability. Physical storage can be dynamically added or removed from storage pools without interrupting services, providing new levels of flexibility, availability, and performance.

Oracle Solaris ZFS protects all data by 256-bit checksums, resulting in 99.99999999999999999-percent error detection and correction. Oracle Solaris ZFS constantly reads and checks data to help ensure it is correct, and if it detects an error in a storage pool with redundancy, Oracle Solaris ZFS automatically repairs the corrupt data. A redundant RAID_Z configuration can have single-parity, double-parity, or triple-parity, which means that one, two, or three device failures can be sustained, respectively, without and data loss. These capabilities contribute to relentless availability by helping to protect against costly and time-consuming data loss due to hardware or software failure, and by reducing the chance of administrator error when performing file system-related tasks.

Oracle Solaris ZFS software also provides the data services needed to protect data far beyond what exists today in traditional storage systems. It optimizes file system reliability by maintaining data redundancy on commodity hardware through the delivery of basic mirroring, compression, and integrated volume management. Oracle Solaris ZFS seamlessly and transparently supports new hybrid disk storage pools that include Flash technology for superior application performance.

Reliable Networking

Reliable and high-performance connectivity is an essential aspect of an enterprise IT infrastructure. Oracle Solaris supports many innovative features that detect and repair network-related failures, even in virtualized environments. Integrated security technology contributes to data integrity and overall uptime.

Redundant Networking and Network IP Multipathing

In addition to traditional support for multiple network interfaces connected to different network subnets, Oracle Solaris running on Oracle SPARC servers also provides support for redundant network interfaces that are connected to a single subnet. IP Multipathing provides both failover and IP link aggregation. A number of key features of redundant networking that work to improve the availability and performance of Oracle SPARC servers are listed below.

- Failure detection, the ability to detect when a network adapter fails and automatically switch (failover) network access to an alternate network adapter.
- Repair detection, the ability to detect the repair of a previously failed network adapter and automatically switch back (fail back) the network access to this interface.
- Outbound load spreading, outbound network packets spread across multiple network adapters to achieve higher throughput. Load spreading occurs only when network traffic is flowing to multiple destinations using multiple connections.

Support for Virtualized Networking and I/O

Oracle Solaris contains technology to support and virtualize components and subsystems on the SPARC T-Series processor, including support for the on-chip PCI Express interface and cryptographic processors. As a part of a high-performance network architecture, multithread-hot device drivers are provided so that applications running within virtualization frameworks can effectively share I/O and network devices, maximizing utilization and increasing ROI.

Oracle Solaris Cluster

As an Oracle customer, Commerzbank AG has incorporated Solaris Containers and Oracle Solaris Cluster into the company's "Solaris Virtual Grid Services (SVGS)," a virtualization design for their IT environment. Each SVGS-cluster consists of five nodes where applications are installed in Solaris Containers and distributed according to their load profile to the nodes. Oracle Solaris Cluster enables Commerzbank to move the Solaris Container among the nodes. This virtualization concept not only enabled Commerzbank to extend the use of their servers but also enabled them to implement a disaster recovery solution between two datacenters without extra cost.

Keeping application data and services in a single system exposes businesses to potential failure from any component of the configuration. To limit outages due to those single points of failure, mission-critical services need to be run in clustered physical servers that efficiently and smoothly take over the services from failing nodes, with minimal interruption to the customer experience. Oracle Solaris Cluster provides the best HA solution for Oracle SPARC servers running Oracle Solaris. Tightly coupled with Oracle Solaris, Oracle Solaris Cluster detects failures without delay ("zero-second delay"), provides much faster failure notification, application failover, and reconfiguration time. Significantly reducing services recovery time achieves much faster resumption of IT services. Oracle Solaris Cluster on Oracle SPARC servers:

- Integrates tightly with the Predictive Self Healing framework and supports the SMF-controlled applications in Oracle Solaris Containers
- Makes extensive use of Oracle storage management and volume management capabilities
- Supports Oracle Solaris ZFS as a failover file system and as a boot file system, allowing the use of ZFS storage as the single file system type used
- Leverages ZFS features such as pooled storage, built-in redundancy, and data integrity

- Uses Oracle Solaris I/O multipathing (MPxIO) to represent and manage devices that are accessible through multiple I/O controller interfaces within a single instance of Oracle Solaris
- Supports network IP multipathing to enhance resiliency and throughput in a clustered environment
- Integrates with Oracle Enterprise Manager Ops Center
- Offers secure administrative capabilities through Oracle Solaris RBAC, enhancing security

High Availability for Mission-Critical Data and Application Services

Oracle Solaris Cluster running on Oracle SPARC servers monitors all hardware and software components and tolerates failures by exploiting hardware redundancy using software algorithms to ensure reliability of mission-critical data and services.

- **Fencing.** Preserving integrity of data within a cluster of servers through flexible disk fencing options to prevent failing server nodes from updating the shared data.
- **Quorum.** Preventing partitions such as split brain and amnesia in a cluster of servers through a majority voting scheme using quorum devices as an external tiebreaker. All quorum devices are closely monitored to ensure maximum availability.
- **Resource Manager.** Application services running among the cluster of servers can be failed over either as a single instance application, together with the supporting components of networking, storage, and file systems, or restarted and load-redistributed on surviving servers.

A Single High Availability and Disaster Recovery Solution for Multitier Oracle Applications and Databases

Oracle Solaris Cluster software enables HA for local datacenters to business continuity and global disaster recovery solutions for evolving datacenter needs. The software leverages proven availability and virtualization features in Oracle Solaris and Oracle SPARC servers, and supports an industry-leading portfolio of commercial and open source applications across the database and business logic tiers. Examples include Oracle Application Server, Oracle E-Business Suite, Oracle Databases, Siebel CRM, MySQL, Web server technologies, and more.

Oracle Solaris Cluster supports Oracle Database and Real Application Clusters, and tightly integrates with Oracle Clusterware. It also provides flexibility for the cluster infrastructure by supporting a wide range of networking and storage options such as InfiniBand, ASM, NAS, QFS, and hardware in thoroughly tested configurations.

Oracle Solaris Cluster supports the following deployment scenarios:

- **Local Datacenter.** Oracle Solaris Cluster can protect applications distributed on clusters up to 16 physical servers, supporting both failover ("active/passive") or scalable (multinode active/active) applications.

- **Campus Cluster.** Oracle Solaris Cluster automates application services failover procedures across clusters of systems in different sites within the same campus or metropolitan area. This limits service interruption due to local outages that cause the shut down of a whole datacenter.
- **Disaster Recovery.** Oracle Solaris Cluster Geographic Edition enables customers to manage application failover and data replication from a primary geographic site to a secondary site across unlimited distances, protecting data integrity in the event of a disaster. This solution supports Oracle Data Guard for a complete end-to-end Oracle RAC global disaster recovery configuration.
- **Virtualization.** Oracle Solaris Cluster works seamlessly with Oracle's virtualization technologies to consolidate multiple applications within the same cluster of physical servers, optimizing resource use, ensuring availability of mission-critical services, and improving data integrity.
  - **Oracle VM Server for SPARC.** Oracle Solaris Cluster manages Oracle VM Server for SPARC in two ways. A guest domain can be considered as a standalone and opaque resource that can be failed over to another server regardless of what it carries. Or, it can be considered as a cluster node where Oracle Databases and Applications are run and managed independently, together with associated resources and dependencies similar to a physical cluster node.
  - **Oracle Solaris Containers.** As with Oracle VM Server for SPARC, multiple options are available for when using Oracle Solaris Containers. The "failover" approach treats containers as "black boxes," which can be easily restarted or moved among cluster nodes. This solution supports Solaris 8, 9 and 10 Containers. A more comprehensive solution is Oracle Solaris Containers cluster. Oracle Databases and Applications, including Oracle E-Business Suite, Siebel CRM 8, and Oracle single instance and RAC Databases, are supported to run in Oracle Solaris Containers clusters.[2] An Oracle Solaris Containers cluster is a virtual cluster of Oracle Solaris Containers that allows applications to run fully isolated across the clustered machines. Multiple Oracle and third-party applications and database versions can be consolidated into one physical cluster for highly reliable service at a much lower cost while still benefitting from Oracle Solaris Container's advantages of security isolation, resource management, and fault isolation. Oracle Solaris Containers is supported with Oracle RAC 10*g* R2 and 11*g* R1 with Oracle Solaris Cluster on Oracle SPARC servers. Oracle Solaris Container cluster is the most complete Oracle Solaris-based HA solution that leverages software licensing models based on CPU utilization. In some situations, the costs of the applications and databases that co-exist in the same cluster of hardware can be reduced by using Oracle Solaris Containers clusters.

[2] Check the Oracle Solaris Cluster web site for the latest list of tested and supported Oracle applications

Scalable Performance

"As a result of going to SPARC, we improved our response time and we're sitting at less than 10% system utilization with 5x the business we had nine months ago. We have a scalable server and storage platform that can provide air cover for our sales team, and reports we get from our enterprise customers say that there's nothing faster out there."

— David Simon, Chairman, SearchForce, Inc.

- Since launch, Sun SPARC Enterprise M-Series systems such as the SPARC Enterprise M9000 have earned more than 24 world records and "product firsts."
- Since launch, SPARC T-Series systems such as the SPARC T3-4 have earned more than 176 world records and "product firsts."

TABLE 2: ORACLE SOLARIS SCALABILITY

SCALABILITY FEATURE	ORACLE SOLARIS 10
64-bit addressing	Since 1996
128-bit file system	Yes
Maximum CPU threads	512
Maximum RAM	4 TB
Maximum file system size	16 Exabytes
Maximum file size	16 Exabytes

Oracle Solaris 10 is specifically designed to optimize the considerable resources of SPARC M-Series and SPARC T-Series systems, and offers impressive scalability, as shown in Table 2.

Oracle Solaris has incorporated many features to improve scalability and performance on SPARC-based systems, such as the following.

Multithread Awareness

Oracle Solaris is optimized for the SPARC M-Series and SPARC T-Series processor hierarchies so that the scheduler can effectively balance the load across all the available pipelines. Even though it exposes every physical processor strand as a logical processor (up to 128 per chip), Oracle Solaris understands the correlation between cores and the threads they support, and provides a fast and efficient thread implementation. Independent software threads are first spread across processors, then across cores within a processor, then across pipelines within a core.

NUMA Optimization—MPO

As systems grow larger, with more processor sockets and more memory, the ability of a processor to access memory becomes more challenging—all processors cannot directly access all memory at the same latency. Multiprocessor systems generally demonstrate some memory locality effects, which means that when a processor requests access to data in memory, that operation will occur with somewhat lower latency if the memory bank is physically close to the requesting processor. Oracle SPARC servers are designed with a NUMA architecture, enabling processors to directly access some memory at the lowest latency, while accessing the rest of the memory with more latency. Oracle Solaris provides technology that can specifically help applications improve performance on NUMA architectures.

Oracle Solaris uses Memory Placement Optimization (MPO) to improve the placement of data across the physical memory of a server, resulting in increased performance. Through MPO, Oracle Solaris works to help ensure that memory is as close as possible to the processors that access it, while still maintaining enough balance within the system. As a result, many database and technical computing applications are able to run considerably faster with MPO.

Oracle Solaris Internals Optimization

For over 20 years, Oracle Solaris internals have been improved to enhance scalability, enabling Oracle SPARC servers to deliver maximum performance as they have grown to address terabytes of memory and hundreds of processing cores. These include:

- **Large Pages.** Large pages are used to reduce the cost of virtual to physical memory translation and increase overall system performance. The SPARC M-Series and SPARC T-Series processors provide a range of pages sizes up to 256 MB that Oracle Solaris automatically uses in a variety of contexts without application change, including for user and kernel pages, and instruction and data pages. Oracle Solaris automatically uses large pages for Oracle Database instruction pages and for the database SGA on all SPARC systems, and for the database PGA on T-series servers. In addition, Oracle Database allows the end user to tune the selection of `pagesize` for the PGA on all systems through its use of the `memcntl(2)` system call.
- **Mutexes (mutual exclusion operations).** As system size grows, there is a growing likelihood of another thread holding a mutex when a second or third thread attempts to access it. To minimize the performance limitations of heavy mutex contention, Oracle Solaris applies a backoff algorithm that is tuned for the system size and processor characteristics before retrying contended locks. The larger the number of threads or strands, the greater the benefits of the improved mutex backoff algorithms.
- **Intimate Shared Memory (ISM).** The use of ISM allows the processes to share kernel data structures that store virtual to physical translations, reducing the cost of a TLB miss. In addition, the SPARC T-Series and the SPARC M-Series processors implement a unique feature called the shared MMU context, which is used for ISM segments and allows threads to share translations in the hardware TLB cache, reducing the TLB miss rate. Large pages, ISM, and shared context combine

seamlessly to optimize access to large memory and the Oracle Database SGA on Oracle SPARC T-series and M-series servers.

- **Library Optimization.** Oracle Solaris provides multiple implementations of common utility functions such as `memcpy(3C)`, each of which is optimized for a different SPARC processor. The versions are kept in shared libraries that are updated as new processors are developed, and the linker dynamically selects the best version at application start time based on the processor that is present. No change to the application is required to get the fastest version for the latest processor.
- **64-bit Mode.** 64-bit capabilities offer extended precision, large dataset support, and a larger virtual address space.

Successful enterprise-class servers efficiently process CPU, memory, and I/O workloads for middleware and databases. Building on a proven track record, Oracle Solaris unlocks the proven performance capabilities of the SPARC M-Series and SPARC T-Series processors. Significant performance innovation comes from optimizations of the individual cores and the overall multicore microarchitecture, which increase both single-threaded and multithread performance. As a result, the Oracle Solaris kernel and existing single- or multithreaded applications will run faster, with no code changes or recompilation necessary. Oracle Solaris running on SPARC-based systems are designed for optimized, end-to-end performance, reducing or eliminating bottlenecks in memory and I/O subsystems. This is highlighted in a number of world-record benchmarks, including the following.

World Record Performance[3]

Oracle Database 11*g*, Oracle Applications, Oracle Solaris, and Oracle's SPARC servers continue to set world records in performance and affordability. This includes:

- **SPECjEnterprise2010 Benchmark**. The SPARC T3-4 server achieved a new world-record result for all single application server systems on a multi-tier SPECjEnterprise2010 benchmark, which uses scenarios based on real-world CRM, manufacturing and supply chain management business cases. The SPARC T3-4 server beat IBM's Power 750 Express result by 32 percent at the application tier and a SPARC T3-2 server outperformed IBM PS702 at the database tier. Oracle's solution consumed half the physical space and delivered 3x better performance per rack unit (RU) over IBM's solution.[4]

[3] See www.oracle.com/us/solutions/performance-scalability/sun-sparc-enterprise-servers-069502.html for SPARC Enterprise M-Series benchmark information, and www.oracle.com/us/solutions/performance-scalability/sun-sparc-enterprise-t-servers-078532.html for SPARC T3 benchmarks.

[4] SPEC and SPECjEnterprise are registered trademarks of the Standard Performance Evaluation Corporation. Results from www.spec.org as of 9/20/2010. SPARC T3-4 – 9,456.28 SPECjEnterprise2010 EjOPS. IBM Power 750 Express – 7,172.93 SPECjEnterprise2010 EjOPS.

- **SPECjvm2008 Benchmark.** One SPARC T3-2 server posted a new world record result on SPECjvm2008, a general-purpose, multi-threaded Java benchmark. The combination of a SPARC T3-2 server, Oracle Solaris 10, and Oracle's Java HotSpot Virtual Machine (VM) offer customers using Java the ability to run their applications on a proven and stable environment with the best performance in the industry.[5]
- **Siebel CRM Benchmark.** The SPARC T3-1 server achieved outstanding results on this benchmark, which simulates service representatives running Siebel Financial Services Call Center applications and seamless integration with Siebel Web Services, using the Siebel Enterprise Application Integration component. A single SPARC T3-1 server, running Siebel CRM Application Servers, and a SPARC T3-2 server using Oracle Solaris Containers to run Oracle iPlanet Web Server and Oracle Database 11*g*, delivered an outstanding result of 13,000 active Siebel benchmark users with Siebel CRM v.8.1.1.
- **Oracle E-Business Suite R12.1.2 Benchmark.** SPARC T3-2 and Sun SPARC Enterprise M5000 servers running on the application- and database-tier respectively, are the first to achieve the result of 4,000 users on the online (OLTP) component of the Oracle E-Business Human Resources Self-Service (HRSS) business flow.[6] This result demonstrates that a SPARC T3-2 server with only one-fourth of its compute resources utilized, Sun SPARC Enterprise M5000 server, and Sun Storage F5100 Flash Array (instrumental in maintaining excellent average transaction response times) are well-suited for OLTP-application environments while leaving customers plenty of room for growth.
- **Oracle Communications Order and Service Management Benchmark.** Oracle Communications Order and Service Management enables communications service providers to address the enterprise-wide central order management challenges that are critical to their businesses. The benchmark simulates fulfillment of orders that are executed as many tasks, and measures throughput as the number of completed Tasks Per Second (TPS). Two SPARC T3 servers with Oracle Solaris 10, a SPARC T3-1 running Oracle Communications Order and Service Management 7.0 cluster and Oracle WebLogic Server 11*g*, and a SPARC T3-2 server running Oracle Database 11*g*, handled a large number of orders with a record score of 1,392 TPS. This result represents 2.4x performance improvement over an x86-based solution using three Dell servers.[7]
- **PeopleSoft Enterprise Financials 9.0 (Day in the Life) Benchmark.** A SPARC T3-1 server running a PeopleSoft Web and Application Servers, and a Sun Enterprise SPARC M5000 server with

[5] SPEC and SPECjvm are registered trademarks of the Standard Performance Evaluation Corporation. Results from www.spec.org as of 9/20/2010. SPARC T3-2 server – 320.52 SPECjvm2008 Peak ops/m.

[6] Oracle E-Business Human Resources Self-Service (HR SS) business flow is a part of an extra large workload that includes 20,000 online users and two batch job with 750,000 order lines and 250,000 payroll employees.

[7] Application tier: 2 x Dell PowerEdge R610 (2 x E5530, 2.4 GHz). Database tier: 1 x Dell PowerEdge 2950 (2 x X5460, 3.16 GHz) – 572 tps.

Sun Storage F5100 Flash Array running Oracle Database 11*g* R2 posted the first result on this benchmark using a large database model. A "Close-the-Books" process that consists of concurrent batch jobs and simulates 1,000 online users completed in 33 minutes. This solution showcases an ideal environment for hosting complex multitier PeopleSoft Financial Applications for enterprise-scale customers.

- **Oracle JD Edwards EnterpriseOne Benchmark.** Using a "Day in the Life" test that represents most popular JD Edwards EnterpriseOne applications, a SPARC T3-1 server running Oracle Application Server 10*g* R3 and JD Edwards EnterpriseOne 9.0 in Oracle Solaris Containers, and a Sun SPARC Enterprise M3000 server running Oracle Database 11*g* delivered a new record result of 4,200 users. This solution provides customers with high performance and scalability in a compact form factor with built-in virtualization and security features, reducing costs.
- **Consumer E-Commerce Site Benchmark.** This in-house workload mimics a popular online auction site and includes functions such as creating an auction, submitting bids, user login/logout, and account setup. A SPARC T3-1 server with Oracle WebLogic Server 10.3.3 and a Sun SPARC Enterprise M4000 server with Oracle Database 11*g* R2, both running Oracle Solaris, demonstrated outstanding performance by supporting 19,000 concurrent users.[8] The SPARC T3-1 server allows customers to balance a large number of interactive user sessions by scaling the number of WebLogic server instances almost linearly from one to four, while maintaining subsecond response time and leaving processing capacity for additional growth.
- **Cryptography Benchmarks.** Industry-leading, no-cost cryptography, built into the SPARC T3 product line, provides enterprise customers with strong security capabilities, and helps ensure regulatory compliance while reducing space and power consumption.
  - **Applications**. Securing Oracle WebLogic applications and XML Web services on SPARC T3 servers running Oracle Solaris and Java is possible without adding any new code. Applications may access hardware-assisted cryptography via an application-transparent facility to speed up encryption using standard protocols, such as SSL, by up to 12x at the network level and by up to 3x at the application level when compared to non-accelerated deployments.
  - **Database.** Oracle's Transparent Data Encryption (TDE) feature of the Oracle Database 11*g* simplifies the encryption of data, preventing unauthorized access from the operating system. The hardware crypto-acceleration enabled a SPARC T3-1 server to complete a full table scan query on a TDE tablespace 8x faster, while index creation finished 2.1x faster compared to cryptography performed in software.

[8] SPARC T3-1 (one Weblogic 10.3.3 application server instance) – 5,000 users, 1,302 Ops/sec. SPARC T3-1 (four Weblogic 10.3.3 application server instances) – 19,000 users, 4,815 Ops/sec.

- **x86 to SPARC Virtualization Benchmark.** SPARC T3 systems enable users to migrate the database workloads off older x86 servers to a single SPARC T-series server. Specifically, up to 30 x86 servers running Oracle Database 11*g* can be consolidated onto a single SPARC T3-2 server with a Sun Storage F5100 Flash Array, using Oracle Solaris 10 with Oracle Solaris Containers in a secure, virtualized environment. To conduct this test, 30 Solaris Containers were configured on a SPARC T3-2 server using the same parameters and workload levels as recorded on each individual x86 server, thus assuring about the same transactional throughput and response times. This consolidation demonstrates a 10x physical footprint reduction, 6.7x better power consumption and reduced management costs, while leaving customers with 20-percent room for additional growth on the SPARC T3-2 server.[9]
- **PeopleSoft Enterprise Payroll 9.0.** A Sun SPARC Enterprise M4000 server achieved world-record performance on this popular human capital management (HCM) application benchmark using Oracle Database 11g running on Oracle Solaris 10. The Sun SPARC Enterprise M4000 server with four 2.53GHz SPARC64 VII processors and a Sun Storage F5100 Flash Array processed 240,000 employee payroll checks using PeopleSoft Enterprise Payroll 9.0 with three different execution strategies with an average CPU utilization of only 25 percent. The Sun SPARC Enterprise M4000 server combined with Sun FlashFire technology running eight parallel streams on the PeopleSoft Enterprise Payroll 9.0 benchmark using Oracle Database 11*g* output 360,000 payments with a total time of 67.85 minutes.
- **SPEC CPU2006 Benchmark.** A Sun SPARC Enterprise M9000 server, equipped with 64 2.88GHz SPARC64 VII processors and running Oracle Solaris 10, posted the best single-system UNIX result on the SPECint_rate_base2006 and SPECfp_rate_base2006 benchmarks. The Sun SPARC Enterprise M9000 server utilized Oracle Solaris 10 and Oracle Solaris Studio 12 Update 1 compiler software to produce a SPECint_rate_base2006 score of 2,400, the new single-system UNIX world record result.
- **SAP Two-Tier Sales and Distribution (SD).** Oracle Solaris 10 and Sun SPARC Enterprise M9000 server with 2.88 GHz SPARC64 VII+ processors (32 processors, 128 cores, 256 threads) supported 17,430 SD users using SAP Enhancement Package 4 for SAP ERP 6.0 (Unicode) on the two-tier SAP SD Benchmark.

Sun FlashFire Storage

Disk I/O performance is often a bottleneck to application throughput. Oracle's Sun FlashFire products running on SPARC servers use high-performance Flash technology, including on-board

[9] Two socket/3RU SPARC T3-2 running at 80-percent CPU utilization consumes 750W. 1RU Sun Storage F5100 Flash Array consumes 350W. 2RU Sun Fire X4270 (Comstar target) consumes 300W. Thirty 2-socket/2RU x86 systems running at 10-percent CPU utilization consume 320W each.

modules, solid-state drives (SSDs), and PCIe cards to significantly increase application throughput. Flash-based technology offers 10x faster data response times compared to traditional storage devices, and reduces cooling, power, and space requirements. Oracle is setting new benchmark records using Flash technology. In addition, Oracle Solaris ZFS can seamlessly and transparently integrate Flash technology and conventional hard disk drives to create Hybrid Storage Pools, which delivers faster storage performance and lower overall costs.

Network Performance

Oracle Solaris running on Oracle's SPARC servers introduces a new and highly scalable TCP/IP stack that significantly increases network throughput and capacity. This innovative stack speeds packet processing by reducing overhead when processing packets. The advanced design improves the performance of many networked applications by approximately 50 percent—without requiring you to modify a single line of application code. The resulting efficiency helps to drive down costs through increased scalability, allowing your systems to support more connections and enabling network throughput to grow linearly with the server's number of CPUs and NICs. Oracle Solaris 10 TCP/IP stack is tuned for 10 Gigabit Ethernet, wireless networking, and hardware offloading technologies.

Security

"By virtualizing our applications into Solaris Containers and using the integrated 10Gigabit Ethernet and cryptographic acceleration embedded into the SPARC T-Series servers, we have also have been able to boost system utilization and security and improve system administrator productivity, while reducing data centre power, cooling and space requirements."

— Kip Turco, Senior Vice President, Motricity

Oracle Solaris provides a sophisticated network-wide security system that controls the way users access files, protect system databases, and use system resources. From integrated security services and applications, to enhanced encryption algorithms, to an enterprise firewall for network protection, Oracle Solaris sets a high standard for operating system security by addressing security needs at every layer. For example, it is optimized to work with the built-in security and encryption capabilities of the SPARC T-Series servers, as outlined below. Extended security features are also available, including authentication, data integrity, data privacy, and single sign-on capabilities so that tampering, snooping, and eavesdropping do not compromise data or associated transactions.

- Oracle Solaris 10 provides security features previously only found in Oracle's Trusted Solaris OS. It delivers a secure environment right out of the box, and can be further hardened and minimized as needed, helping to reduce the risk that a system or application can be compromised.
- Oracle Solaris 10 offers RBAC, Process Rights Management, and least privilege. These technologies reduce security risk by granting users and applications only the minimum capabilities needed to perform tasks. System administrators can grant—or deny—a large number of discrete privileges to

any process on the system to create effective security policies, minimize the likelihood of hostile actions, control access to data, and ensure compliance with regulatory requirements.

- As an optional layer of secure label technology in Oracle Solaris 10, Oracle Solaris Trusted Extensions allow data security policies to be separated from data ownership.

Integrated with Oracle SPARC T-Series Servers

The Oracle SPARC T-Series and Sun SPARC Enterprise M-Series service processors are also secure out of the box. All data services must explicitly be enabled, with only the serial port enabled by default. The service processors also implement a form of RBAC for account security. Users can be assigned specific roles with restricted access and capability as the business dictates. On the M-Series, this control can also be done on a domain-by-domain basis. This has the same effect as the Oracle Solaris 10 feature least privilege (discussed later).

SPARC T3 processors were designed with a dedicated, integrated cryptographic accelerator unit for each of the eight cores. Integrated cryptographic acceleration means Oracle Solaris applications can run securely without the extra cost of a separate cryptographic processor, and without the high performance penalty previously associated with secure operation. SPARC's integrated cryptographic units support the ten most common ciphers and secure hashing functions, including NSA-approved algorithms. And, they outperform competing accelerators by more than 10x, with minimal performance impact.

The latest SPARC T3-series processors extend algorithm support by introducing symmetric key-based encryption and decryption mechanisms, such as Data Encryption Standard (DES), Triple DES (3DES), Advanced Encryption Standards (AES-128, AES-192, and AES-256), RC4, as well as hashing operations such as Message Digest 5 (MD5) algorithm, SHA1, SHA256, and Elliptic Curve Cryptography (ECC) mechanisms, such as the ECCp-160 and ECCb-163 algorithmsSHA-384/SHA-512, Kasumi Bulk Cipher, and Galois Field Operations. An on-chip Random Number Generator supports random number generation operations intended for cryptographic applications. The stream processing unit (SPU) is designed to achieve wire-speed encryption and decryption on both of the processor's 10 GbE ports.

RSA operation is an important component of the Secure Sockets Layer/Transport Layer Security (SSL/TLS) full handshake. Each core of the SPARC T-Series processors includes a Modular Arithmetic Unit (MAU) that supports RSA and Digital Signature Algorithm (DSA) operations. RSA operations utilize a compute-intensive algorithm that can be off-loaded to the MAU. Indeed, the MAU is capable of sustaining more than 30,000 RSA-1024 operations per second on systems with an UltraSPARC T2/T2 Plus processor. Moving RSA operations to the MAU speeds SSL/TLS full handshake performance and frees the CPU to handle other computations.

The Oracle Solaris Cryptographic Framework Library

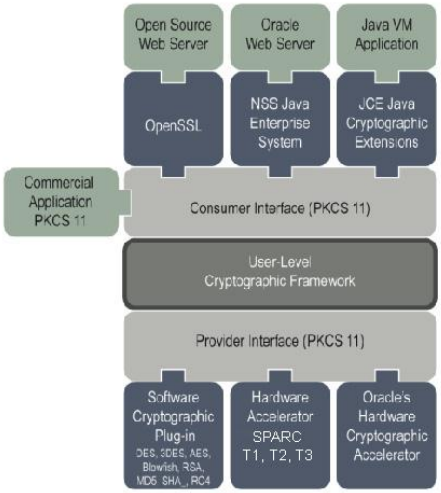

Figure 2: Oracle Solaris Cryptographic Framework is standardized and extensible—current and future cryptographic choices can easily plug in and take advantage of hardware and software capabilities.

The Oracle Solaris Cryptographic Framework provides cryptographic services to applications and kernel modules in a manner seamless to the end user, and brings direct cryptographic services, such as encryption and decryption for files, to the end user. The user-level framework is responsible for providing cryptographic services to consumer applications and the end-user commands. The kernel-level framework provides cryptographic services to kernel modules and device drivers. Both frameworks give developers and users access to software-optimized cryptographic algorithms.

Oracle Solaris Cryptographic Framework provides cryptographic services for kernel-level and user-level consumers, as well as several software encryption modules. Oracle Solaris Cryptographic Framework continues to include Kernel SSL proxy (KSSL), which off-loads SSL processing from user applications and enables them to transparently take advantage of hardware accelerators, such as those available in SPARC T-Series processors.

The Oracle Solaris Cryptographic Framework provides the PKCS#11 industry standard. It is accessible to Java applications on Oracle Solaris as the default Java Cryptographic Extension (JCE) provider. For OpenSSL applications a "pkcs11" OpenSSL ENGINE is available for them to offload cryptographic algorithms to the Oracle Solaris Cryptographic Framework. Applications using the Mozilla Network Security Services (NSS) API can be configured to use the crypto framework via PKCS#11. It provides cryptographic services to users and applications through commands, a user-level programming interface, a kernel programming interface, and user-level and kernel-level frameworks.

The Oracle Solaris Cryptographic Framework can provide performance and security benefits to both system administrators and developers. For example, applications and directory services can program to a standard interface (PKCS#11 providers) from Java or other development environments and take full

advantage of a range of hardware cryptographic accelerators for SSL, token cards, or secure network transport between data repositories and business logic layers.

For applications that utilize any of the above-mentioned cryptographic APIs, performance of cryptographic routines is automatically improved without recompilation. For applications that use a private cryptographic library, recompilation, or linking to one of these API's will ensure that full hardware acceleration of cryptographic routines is achieved. Note that many system services in Oracle Solaris, such as IPSec/IKE and Kerberos authentication already take advantage of the Cryptographic Framework and will automatically use the hardware acceleration provided by the SPARC T–Series processors.

Preventing Attacks

Oracle Solaris also takes advantage of the SPARC's capability to prevent attacks by disallowing application code to be executed from the application's stack. This type of attack, known as "stack smashing" could allow an otherwise unprivileged application to gain access to memory or processes that it should not have. Preventing this type of attack requires that Oracle Solaris and the SPARC chipset work together; this protection is automatic for all 64-bit applications on the OS, and available for all older 32-bit applications with a simple system configuration setting.

Least Privilege

Most UNIX operating systems run a large number of their system processes with root privileges. These processes then have the capability to read and modify other processes, memory, I/O devices, and so on. While this gives these system processes the power needed to perform their tasks, it also provides them with unnecessary access to other protected parts of the system. Many software exploits count on this escalated privilege to gain superuser access to a machine via bugs like buffer overflows and data corruption. To combat this problem, Oracle Solaris 10 includes a new least privilege model, which gives a specified process only a subset of the superuser powers and not full access to all privileges.

The least privilege model evolved from Oracle's experiences with Trusted Solaris and the tighter security model used there. The Oracle Solaris 10 least privilege model makes it convenient for normal users to do things like mount file systems, start daemon processes that bind to lower numbered ports, and change the ownership of files. At the same time, it also restricts access by programs that previously ran with full root privileges in order to perform a privileged task such as binding to ports lower than 1024, reading from and writing to user home directories, or accessing the Ethernet device. Since `setuid` root binaries and daemons that run with full root privileges are rarely necessary under the least privilege model, an exploit in a program no longer means a full root compromise. Damage due to programming errors like buffer overflows can be contained to a non-root user, which has no access to critical abilities like reading or writing protected system files or halting the machine.

Common Criteria

Oracle Solaris has been tested on all of Oracle's SPARC servers against the stringent Common Criteria testing process and has achieved Evaluation Assurance Level 4+ certification against three protection

profiles: Controlled Access, Role-Based Access Control, and Labeled Security. This allows customers to run their applications on one of the most highly certified operating systems in the world without the need for special programming or modifications to their applications.

Oracle Solaris 10 with Trusted Extensions utilizes User and Process Rights Management, Oracle Solaris Containers (see next section), file systems, and networking and does not require a new or separate kernel. Best of all, it does not require third-party developers to requalify their applications to run them with sensitivity labels. Because it's an extension to the Oracle Solaris 10 security policy, Trusted Extensions technology is flexible and quick to deploy: You can add new applications, new users, and more, very quickly, without extensive analysis of each application—without the need to write complex, error-prone security policies that require a system reboot.

Oracle Server Virtualization

The Capabilities Integration Environment consolidated servers using both Oracle Solaris Containers and Oracle VM Server for SPARC on Oracle SPARC T-Series servers, reducing rack space to achieve a 13:1 consolidation ratio and decreasing server deployment time by more than 90%. ZFS simplified management and produced 3:1 compression on its Oracle database

— U. S. Air Force[10]

Enterprise users need choice when it comes to server virtualization and consolidation, and flexibility with respect to application, OS, and network virtualization methods. Oracle offers a comprehensive portfolio of virtualization solutions to address enterprise computing customers. Oracle SPARC servers are the leading platform to have hard partitioning capabilities that provide the physical isolation needed to run independent operating systems.

Figure 3: Oracle offers the industry's most complete virtualization portfolio.

[10] oracle.com/us/corporate/customers/060237.pdf

Virtualization provides the ability to deliver more work from an existing IT infrastructure by increasing utilization. As the power of today's servers continues to increase well beyond the needs of a single application stack, the cost-savings benefit of virtualization make it a must-have technology. Virtualization helps consolidate legacy applications from multiple obsolete hardware platforms onto a smaller number of up-to-date, more powerful, and more energy-efficient servers. It supports moving today's applications from a large set of underutilized servers to a smaller set of more powerful servers, helping to reduce the number of servers to house, power, cool, and maintain. Raising utilization levels helps to reduce inefficiency, helping with the space, power, and cooling crunch. Organizations are increasingly using virtualization to increase business agility, which increase speed and flexibility in delivering IT services to support business goals.

Oracle supports several complementary virtualization technologies, each of which provide different degrees of isolation, resource granularity, and flexibility. Oracle supports virtualization technologies that allow multiple OS (and application) instances to run on the same server, while each instance has the illusion of owning its own hardware resources.

These capabilities are built into Oracle Solaris and Oracle SPARC servers—there are no additional costs to use them.

- Dynamic Domains provide hardware partitioning capabilities on selected Sun SPARC Enterprise M-Series servers. This technology allows physical hot-swap of components in the system without shutting down services. Hybrid virtualization is achieved by combining Dynamic Domains and Solaris Containers.
- Oracle VM Server for SPARC offers a hybrid of partitioning and virtualization fully exploiting the unique advantages of CMT technology to provide a more optimized virtual machine environment and still providing all the advantages of the SPARC hardware platform and Oracle Solaris, including full binary compatibility.
- Oracle Solaris Containers provide security and resource isolation that allows multiple virtual Oracle Solaris environments to share the same OS instance. Oracle Solaris Containers complements the capabilities of Oracle VM Server for SPARC and Dynamic Domains, and increases security and utilization on all of Oracle's SPARC servers.

Oracle VM Server for SPARC and Oracle Solaris Containers are multithreaded to maximize performance and utilization.

Oracle VM Server for SPARC

Oracle's SPARC servers running Oracle Solaris are the only systems today that provide completely integrated application separation technologies at every level of the product stack, fully supported from one company—Oracle. Oracle VM Server for SPARC, previously called Sun Logical Domains, leverages the built-in SPARC hypervisor to subdivide and reconfigure supported platforms' resources (CPUs, memory, network, and storage) by creating partitions called logical (or virtual) domains. Each logical domain can run an independent operating system. Oracle VM Server for SPARC provides the flexibility to deploy multiple Oracle Solaris OS instances simultaneously on a single platform. Oracle

VM Server for SPARC also allows you to create up to 256 virtual servers on one system to take advantage of the massive thread scale offered by the CMT architecture. SPARC T-Series servers come with the right to use (RTU) for Oracle VM Server for SPARC, and the software is pre-installed.

Oracle VM Server for SPARC integrates both the industry-leading CMT capabilities of the SPARC T-Series processors and Oracle Solaris. This combination helps to increase flexibility, isolate workload processing, and improve the potential for maximum server utilization. To facilitate agile datacenters, Oracle VM Server for SPARC domains can be migrated between physical servers, and system resources such as CPUs, virtual I/O devices, memory, and cryptographic units can be dynamically reconfigured.

Oracle SPARC servers running Oracle Solaris are the leading platform with the hard partitioning capability that provides the physical isolation needed to run independent operating systems. Many customers have already used Oracle Solaris Containers for application isolation. Oracle VM Server for SPARC provides another important feature with OS isolation. This gives you the flexibility to deploy multiple operating systems simultaneously on a single SPARC T-Series server with finer granularity for computing resources. For SPARC T-Series processors, the natural level of granularity is an execution thread, not a time-sliced microsecond of execution resources. Each CPU thread can be treated as an independent virtual processor. The scheduler is built into the CPU, without the extra overhead for scheduling in hypervisor. You just have one software scheduler—the Solaris scheduler—to dispatch workloads to virtual CPUs, which are effectively physical CPU threads. What you get is a virtualization solution with "bare-metal" performance—lower overhead, and higher performance and scalability.

Your organizations can couple Oracle Solaris Containers and Oracle VM Server for SPARC with the breakthrough space and energy savings afforded by SPARC T-Series servers to deliver a more agile, responsive, and low-cost environment.

Oracle Solaris Containers

"We estimate that Solaris Containers have been able to give us the equivalent memory and processing power of ten virtual servers on every physical server. That's resulted in an 80% reduction in space requirements and 65% savings in energy costs."

— Brad Forrester, Systems Operations Manager, SiteWorx

Supported on any of Oracle's SPARC (or x86) server running Oracle Solaris 10, Oracle Solaris Containers isolate software applications and services using flexible, software-defined boundaries. Oracle Solaris Containers provide virtualization and software partitioning, enabling the creation of many private execution environments from a single instance of Oracle Solaris.

Unlike virtual machines, Oracle Solaris Containers provide OS-level virtualization by giving the appearance of multiple OS instances rather than multiple physical machines. Isolation between Containers is accomplished by restricting the scope of system calls, rather than the CPU-intensive task of emulating hardware architectures and instruction sets in software. This makes it possible to create hundreds, even thousands, of Oracle Solaris Containers on a single system. Because of this negligible

overhead, and unlike partitioning or virtual machines, Oracle Solaris Containers can be created in large numbers. For example:

- Individual developers can use safe, isolated test environments.
- Service providers can provide isolated instances of Web servers or database instances.

Hosting applications within individual Oracle Solaris Containers provides administrators the ability to exert fine-grained control over rights and resources within a consolidated server. Containers create very low overhead compared to traditional virtual machines, maximizing the computing resources available to applications. Organizations can safely and more effectively consolidate applications onto a single server. Computing resources—CPUs, physical memory, network bandwidth, and more—can be dedicated to a single application one moment and then shared with others in an instant, all without moving applications or rebooting the system, dynamic domain, or logical domain where the Oracle Solaris Container resides. Physical-to-virtual capabilities can be used to directly migrate an existing Oracle Solaris 10 system into an Oracle Solaris Container; the hosted can be emulated as needed.

Oracle Solaris 8 and Oracle Solaris 9 Containers

With Oracle Solaris 8 and Oracle Solaris 9 Containers, you can safely and easily move your existing applications and environments from a physical server running an older Solaris release to a software Container on the latest Oracle SPARC server running Oracle Solaris 10. This means you can run existing applications on new, more powerful, energy-efficient, and productive systems, and transition these legacy environments to native Oracle Solaris Containers at your own pace. This may save on licensing costs, and offers these existing environments the benefits of Oracle Solaris 10, such as Oracle Solaris DTrace, Predictive Self Healing, and Oracle Solaris ZFS.

Dynamic Domains and Dynamic Reconfiguration

A key feature of the Sun SPARC Enterprise M-Series high-end servers with Oracle Solaris is the ability to partition the available hardware resources into smaller logical systems. Sun SPARC Enterprise M-Series servers offer *hard partitioning* technology in the form of Dynamic Domains. Instantiating a number of Dynamic Domains on a Sun SPARC Enterprise M-Series server divides the system into multiple electrically isolated partitions. Each Dynamic Domain executes a unique instance of Oracle Solaris. Since isolation is instantiated all the way to the hardware, configurations can be created in which software changes, reboots, and potential faults in one domain do not impact applications running in other domains. SPARC Enterprise M-Series servers can provide up to 24 Dynamic Domains, each with configurable amounts of CPU, memory, disk, and I/O resources such as PCI Express and PCI-X slots, and networking.

Dynamic Domains can be used with Solaris Containers to refine resource control and simplify the consolidation of several applications into one domain. As described previously, the Oracle Solaris Containers functionality in Oracle Solaris 10 enables multiple, software-isolated applications to run on a single server or domain.

Dynamic Reconfiguration and Automated Dynamic Reconfiguration (ADR) allow resources to be dynamically reallocated, or balanced, between domains. Utilizing this technology enables a physical or logical restructuring of the hardware components of Sun SPARC Enterprise M-Series servers while the system is running and the applications remain available. This high degree of resource flexibility allows the domain or platform administrator to reconfigure the system easily in order to provision the resources to meet changing workload demands. Disaster recovery can also be used to remove and replace failed or upgraded hardware components while the system is online[11]. CPU, memory, and I/O devices be added or deleted by Dynamic Reconfiguration.

The Reconfiguration Coordination Manager (RCM) is the framework that manages the dynamic removal of system components. By using RCM, you can register and release system resources in an orderly manner. Using RCM, it is also possible to write a script that allows Oracle Database to be alerted when new CPUs or memory are to be removed from the domain, so that the SGA can be dynamically scaled back to allow the board to be removed without shutting down the database.

Comprehensive Management with Oracle Enterprise Manager Ops Center

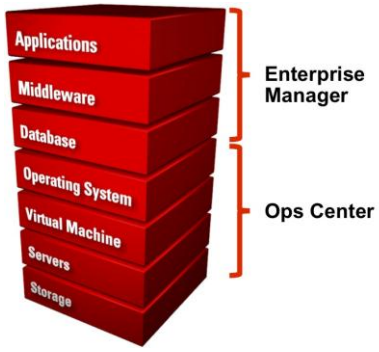

Figure 4: Comprehensive full-stack management, from application to disk

Oracle Enterprise Manager 11*g* is the centerpiece of Oracle's integrated IT management strategy. It connects with Oracle Enterprise Manager Ops Center to form the most comprehensive solution for managing physical and virtual infrastructure, including Oracle's SPARC servers, Oracle Solaris, and Oracle Solaris and SPARC virtualization technologies such as Oracle Solaris Containers and Oracle VM Server for SPARC. It also provides management for other operating systems. The Oracle Enterprise Manager Ops Center Virtualization Management Pack streamlines operations and reduces downtime, and provides an end-to-end management solution for physical and virtual systems through a single web-based console. This solution automates the lifecycle management of physical and virtual systems and is the most effective systems management solution for Oracle's SPARC infrastructure.

[11] SPARC Enterprise M4000, M5000, M8000, and M9000 servers can perform DR to logically move system resources between domains. In addition, SPARC Enterprise M8000 and M9000 servers can perform hot-swap operations to physically add or remove boards from the chassis.

Developer Tools Optimizations

The Oracle Solaris ecosystem, including Oracle Solaris and Oracle Solaris Studio development tools, offers a compelling platform for developers to embrace the breakthrough capabilities of latest systems based on SPARC T-Series, M-Series, and x86 systems. In fact, all top Oracle software is built with Oracle Solaris Studio, including the Oracle Database, Oracle Solaris, the Java VM and key applications such as Peoplesoft, Siebel, JD Edwards, and Hyperion. With a focus on optimizing Oracle Solaris Studio for the latest SPARC and x86 systems, Oracle Solaris Studio is the development platform of choice for Oracle enterprise customers and ISVs.

One of the most significant roles the Oracle Solaris Studio development tools play in the creation of robust applications is their ability to help streamline and automate the optimization process, including tuning the software for greater performance and reliability. Because these tools are designed with an intimate knowledge of both x86 and SPARC-based systems, developers can take maximum advantage of hardware features without specific hardware expertise. Internal testing using well-regarded industry benchmarks showed that Oracle Solaris Studio 12.2 outperforms open-source alternatives by up to 4.8x on floating-point benchmarks and 50 percent in integer benchmarks. Oracle Solaris Studio tools also help increase reliability with comprehensive debugging capabilities, such as highlighting memory leaks. The result delivers a robust choice for both established enterprise datacenters and reliable, leading edge applications.

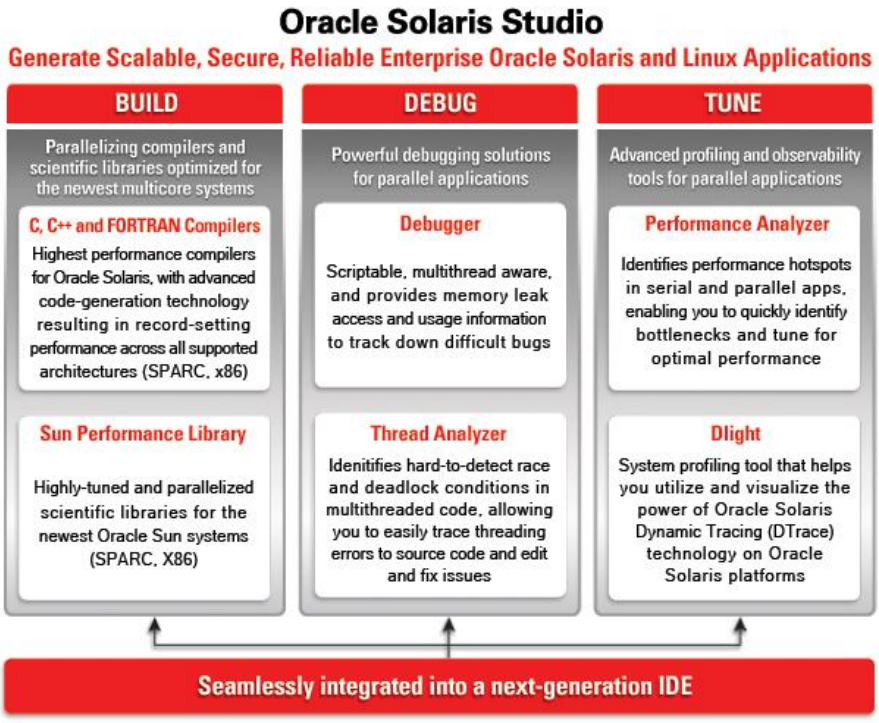

Figure 5: Oracle Solaris Studio is a platform for end-to-end application development

Oracle Solaris Studio

Oracle Solaris Studio improves both the development process and ultimate performance in multicore application development. It serves as a comprehensive build/debug/tune facility for SPARC and x86 systems, offering award-winning compilers (C, C++, Fortran) optimized for the latest multicore architectures, thread analysis tools, compiler auto-parallelization, OpenMP and MPI support, performance analysis tools, multithreaded debugging, and more. Oracle Solaris Studio delivers an advanced suite of tools designed to work together to provide an optimized environment for the development of single, multithreaded, and distributed applications. The debugging and analysis tools take advantage of compiler features to provide application context with high levels of accuracy, leading to more-robust software. Oracle Solaris Studio also comes with an integrated development environment (IDE) tailored for use with the included compilers, the debugger, and the analysis tools. This IDE increases developer productivity with a code-aware editor, workflow, and project functionality. In addition, the parallelizing C, C++, and Fortran compilers; enhanced math routines; and performance analysis tools enable users to maximize the performance of their applications on Sun SPARC server systems, and on other x86-based systems, generating higher ROI from deployment hardware systems.

As shown in Figure 5, Oracle Solaris Studio offers an optimized, comprehensive development environment for SPARC- and x86-based systems. This includes tools and environments to build, debug, and tune applications.

Oracle Solaris Studio IDE

Improving developer productivity, the next-generation IDE provides full edit, compile, and debug support including code completion, error highlighting, semantic highlighting, call graph, memory window, `makefile` wizard and importing capabilities, packaging of application as tar and zip files, SVR4 packages, RPMs, or Debian packages, and much more.

C, C++ and FORTRAN Compilers

Oracle Solaris Studio delivers compilers that produce record-setting application performance—consistently exceeding that of open source alternatives. The C and C++ compilers provide a solid foundation for building robust, high-performance parallel code for the newest SPARC T-Series and M-Series systems, as well as those based on Intel and AMD processors, from Oracle and other OEMs. In addition to supporting the latest language standards, Oracle Solaris Studio software includes GNU C/C++ compatibility features and is source- and object-level compatible with prior releases.

To take advantage of hardware concurrency in multicore systems, the compilers simplify the creation of parallel applications with autoparallelization features. These features enable the compiler to identify safe and productive parallelization opportunities in single-threaded code and automatically convert those segments into multithreaded code. In addition, the compilers support the OpenMP 3.0 specification that introduces task-based parallelism.

The compilers in Oracle Solaris Studio include an array of optimization options for increasing application performance, including:

- **Automatic Parallelization**. By selecting a compiler option, the compiler performs the dependence analysis to determine if a specific part of the program can be executed in parallel. If it can prove this is safe to do, it generates the underlying infrastructure, typically a series of calls to a multitasking library.
- **OpenMP**. OpenMP supports an extensive set of features to specify the parallelism, control the workload distribution, and synchronize the threads. Current OpenMP implementations are built on top of a native threading model.
  The Oracle Solaris Studio compilers support a combination of Automatic Parallelization and OpenMP. This minimizes the effort, since the compiler can first be used to parallelize the application. Those parts that are too complicated for the compiler to handle can then subsequently be parallelized with OpenMP.
- **MPI**. MPI provides for parallelization of applications running across many such systems, often referred to as a compute cluster. Outside of the basic functions to create the processes, as well as send and receive messages, MPI provides a very rich API through an extensive set of additional functions, including various ways to handle I/O.
- **Hybrid**. In a Hybrid parallel application, distributed and shared memory programming models are combined to parallelize an application at two levels. Typically, MPI is used for the distributed memory component, spreading the work over the nodes in a cluster. The process(es) running within one node are then further parallelized using a shared memory model, typically OpenMP. The Hybrid model is a very natural fit for a cluster consisting of multicore nodes. You can run an MPI application across all of the nodes and cores in the system, and use OpenMP for finer-grained parallelization where needed.
  Another reason to consider the Hybrid model is that the memory within one node is used more economically by exploiting shared data through OpenMP, avoiding the need to replicate data. In such cases, this combined model is very suitable. It is often relatively easy to use OpenMP to implement the second level parallelism.

Oracle Solaris Performance Library

The Oracle Solaris performance library is a set of optimized, high-speed mathematical subroutines for solving linear algebra and other numerically intensive problems. It provides a performance boost to high-performance computing, financial, and other compute-intensive applications. The Oracle Solaris performance library contains enhanced and newly added standard routines such as BLAS, FFTPACK, LAPACK, ScaLAPACK, Sparse Solvers, and SuperLU.

Debugger

Ensuring application reliability, the Debugger helps track down difficult bugs in serial and parallel code. It also provides memory leak, access, and usage information. The Debugger is fully integrated into the Oracle Solaris Studio IDE, available via the command line, and available as a high-productivity standalone graphical debugger.

Thread Analyzer

Improving developer productivity and software robustness, the thread analyzer tool identifies hard-to-detect threading errors before they occur. It can detect potential race and deadlock conditions at runtime, map them to source lines in the application, and then enable the user to view the results by using command-line or graphical user interface (GUI) options.

Performance Analyzer

The performance analyzer tool identifies application performance bottlenecks, by specifying not only which functions, code segments, and source lines are having an impact on performance but also by providing the tools necessary to do tuning for optimal performance. From annotated compiler commentary listings in which the compiler indicates a range of information to optimization status and runtime thread performance, users can visualize performance hotspots with the GUI. The performance analyzer tool can be used to profile single-threaded as well as multithreaded applications.

Oracle Solaris provides the ability to observe performance characteristics of applications using performance counters. For example, counters can be used to determine the average cycles per instruction for a given workload, determine how cache/memory intensive an application is, or determine whether there are any serious memory alignment issues with the way that an application lays out its data. Oracle Solaris Studio uses DTrace probes and other techniques to monitor and analyze performance using these counters.

Oracle Solaris DLight

Oracle Solaris DLight is a plug-in for the Oracle Solaris Studio development environment that unites information you get from typical application profiling tools with system profiling tools such as DTrace. DLight is a visual profiling tool that unifies application and system profiling, using DTrace technology on Oracle Solaris platforms, and providing new levels of insight to dramatically reduce development timelines.

Sun Performance Library

Maximizing application performance, the Sun Performance Library provides a set of optimized, high-speed mathematical subroutines for solving linear algebra and other numerically intensive problems. The Sun Performance Library contains enhanced and newly added standard routines including, BLAS, LAPACK, FFTPACK, SuperLU, Sparse Solvers, and ScaLAPACK.

Customers worldwide depend on Oracle Solaris to run their business, with good reason:

- **Unmatched reliability** with Predictive Self Healing for hardware and software faults, data integrity with Oracle Solaris ZFS and DTrace for safe, live observability of the Oracle Solaris kernel and applications.
- **Optimized performance and scalability** for the latest SPARC, Intel, and AMD processor technologies along with efficient datacenter consolidation with Oracle Solaris Containers.

- **Mission critical Oracle Solaris security infrastructure** that provides the compartmentalization and control required by governments and financial institutions.

Conclusion

Oracle Solaris running on Oracle's SPARC servers has continued to demonstrate great success as a mission-critical, enterprise-class OS for scalable performance, advanced reliability, and virtualization, especially when deploying Oracle Database, Middleware, and Applications in the datacenter. The combination of Oracle Solaris on innovative Oracle SPARC servers offers the IT infrastructure you required for enterprises that need a complete, open, and integrated solution.

Oracle Solaris is leveraging more than 20 years of SMP expertise for proven performance in very large multicore processing environments. Developers and system administrators alike can use Oracle Solaris running on systems designed with the Oracle SPARC systems for improved performance, reliability and throughput.

Whether serving Oracle Databases or middleware, enterprise applications, high-performance computing applications, or consolidating multiple lower-powered servers, your IT systems must scale smoothly and intelligently, provide rock-solid security, and virtually nonstop reliability. SPARC-based processors and Oracle Solaris are both widely recognized as the technologies of choice for enterprise and mission-critical applications.

To learn more about each of the specific products, technologies, and capabilities discussed in this document, please refer to the next section, or contact your Oracle representative.

Resources

The following table contains links to useful information related to this paper.

GET THE PRODUCTS	
Oracle Solaris	www.oracle.com/solaris
Oracle's SPARC servers	www.oracle.com/us/products/servers-storage/servers/sparc-enterprise/index.html
Oracle Enterprise Manager Ops Center	www.oracle.com/us/products/enterprise-manager/opscenter/index.html
Oracle Solaris Cluster	www.oracle.com/technetwork/server-storage/solaris/downloads/index.html
Oracle Solaris Studio	www.oracle.com/technetwork/server-storage/solarisstudio/downloads/index.html
Oracle Database 11g	www.oracle.com/us/products/database/
Oracle Siebel CRM	www.oracle.com/us/products/applications/siebel/
Oracle PeopleSoft Enterprise Applications	www.oracle.com/us/products/applications/peoplesoft-enterprise/
Oracle Real Application Clusters (RAC)	www.oracle.com/technology/products/database/clustering/
Oracle Applications	www.oracle.com/us/products/applications/index.html
DEEP DIVE ON THE TECHNICAL	
Oracle Technical Network	www.oracle.com/technetwork/index.html

AVAILABILITY	
Oracle Solaris Predictive Self Healing	www.oracle.com/us/products/servers-storage/solaris/solaris-pred-self-healing-ds-075587.pdf
Oracle Solaris Cluster	www.oracle.com/technetwork/server-storage/solaris/downloads/index.html
Oracle Cluster Documentation Center	http://docs.sun.com/app/docs/doc/821-1261/
Oracle Solaris ZFS	www.oracle.com/us/products/servers-storage/solaris/solaris-zfs-ds-067320.pdf
PERFORMANCE	
Performance Considerations For Developers Utilizing Sun SPARC Enterprise M-Series Servers	www.oracle.com/technetwork/articles/systems-hardware-architecture/mseriesperfconsiderations-163845.pdf
Flash Storage	www.oracle.com/us/products/servers-storage/storage/flash-storage/index.html
SECURITY	
Oracle Solaris Trusted Extensions and Common Criteria	www.oracle.com/technetwork/topics/security/oracle-cc-evalsolaris-083233.html
OTN Oracle Solaris Security	www.oracle.com/technetwork/server-storage/solaris/overview/security-163473.html
Oracle Solaris Security FAQ	http://www.developers.sun.com/solaris/docs/faq-solsec.pdf
VIRTUALIZATION	
Oracle Virtualization	http://www.oracle.com/virtualization
Oracle's Virtualization Blog	blogs.oracle.com/virtualization
Oracle VM Server for SPARC	www.oracle.com/technetwork/systems/logical-domains/index-jsp-141716.html
Oracle VM Server for SPARC—Enabling a Flexible, Efficient IT Infrastructure	www.oracle.com/us/products/servers-storage/servers/sparc-enterprise/vm-server-for-sparc-wp-075964.pdf
Running Oracle Real Application Clusters (RAC) On Oracle VM Server for SPARC	www.oracle.com/technetwork/articles/systems-hardware-architecture/rac-vmsrvrsparc-163927.pdf
Consolidating Oracle's Siebel CRM 8 on Single Oracle SPARC Server	www.oracle.com/technetwork/articles/systems-hardware-architecture/siebel-crm-ha-163926.pdf
Consolidating Applications with Oracle Solaris Containers	www.oracle.com/us/products/servers-storage/solaris/consolid-solaris-containers-wp-075578.pdf
Virtualization with Oracle Solaris 10	www.oracle.com/go/?&src=7011689&Act=4
Increase Application Scalability and Improve System Utilization with Oracle VM Server for SPARC	www.oracle.com/technetwork/articles/systems-hardware-architecture/vm-svr-for-sparc-163928.pdf
DEVELOPER TOOLS	
Oracle Solaris Studio	www.oracle.com/technetwork/server-storage/solarisstudio/overview/index.html
Developing Parallel Programs — A Discussion of Popular Models (Whitepaper)	www.oracle.com/technetwork/server-storage/solarisstudio/documentation/oss-parallel-programs-170709.pdf
Optimizing Applications with Oracle Solaris Studio Compilers and Tools (Whitepaper)	www.oracle.com/technetwork/systems/optimizing-apps-oracle-solaris-stud-150254.pdf
DLight Tutorial for Oracle Solaris Studio	http://developers.sun.com/sunstudio/documentation/tutorials/dlight
DTrace	www.oracle.com/technetwork/server-storage/solaris/overview/observability-163553.html

OTHER	
Using the Solaris 10 Applications Library to Find Apps That Run on the Solaris 10 OS	http://solutions.oracle.com/
• Sun product documentation	http://docs.sun.com
• Oracle Solaris Best in Class podcast series	www.oracle.com/podcasts/servers-storage-podcasts.html

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Oracle is committed to developing practices and products that help protect the environment

Oracle Solaris and Oracle SPARC Systems—Integrated and Optimized for Mission Critical Computing
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