

TECHNOLOGY BRIEF

November 1997

Compaq Computer Corporation

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Eliminating Single Points of Failure and Enabling Rapid Recovery in Server Subsystems

In today's global-operation, information-driven business arena, enterprise servers are expected to be available around the clock, and the value of the data on those servers increases daily. As a result, the cost of server downtime is increasingly prohibitive.

As a technology leader, Compaq continues to develop fault prevention, fault tolerance, and rapid recovery technologies that help make systems more reliable by eliminating single points of failure and minimizing downtime when failure does occur.

This technology brief provides a brief overview of fault prevention, fault tolerance, and rapid recovery technologies as they are implemented in the following Compaq server subsystems:

- *Processor*
- *Expansion*
- *Memory*
- *Primary and secondary storage*
- *Power*
- *Cooling*
- *Management*

An overview of the Compaq Pre-Failure Warranty is also included. Most sections contain references to other Compaq white papers and technology briefs for more in-depth technical information about specific server subsystems.

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**ELIMINATING SINGLE POINTS OF FAILURE
AND ENABLING RAPID RECOVERY IN SERVER
SUBSYSTEMS**

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INTRODUCTION

Compaq researches and develops server subsystems expressly to eliminate single points of failure and minimize downtime through fault-prevention, fault-tolerance, and rapid-recovery technologies. Compaq emphasizes reliability, along with performance and other critical characteristics, because the cost of system downtime is a pressing concern to businesses of every size and variety. According to a 1996 study by Contingency Planning Research, the cost associated with system failure is enormous — as much as \$7.3 million per hour (Figure 1). Even in less network-dependent companies, the cost is in the hundreds of thousands of dollars per hour.

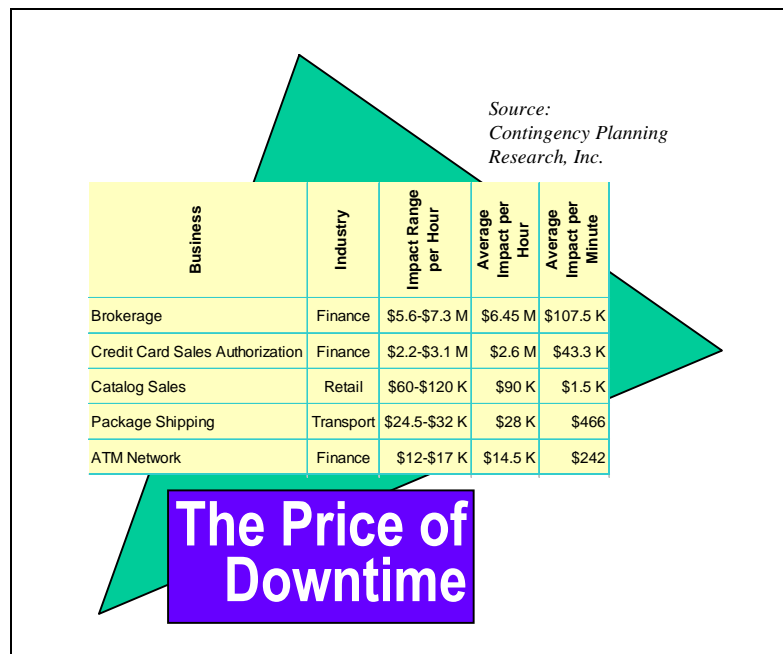


Figure 1: System failure is costly for today's businesses.

In light of the expense of lost business, data, productivity, and administrative time, companies now measure "acceptable" downtime in minutes — or even seconds — according to *Demand Assessment Requirements Tracking Study*, Executive Summary, 1996, by the Standish Group International (Figure 2). System availability is essential for companies in a broad range of industries.

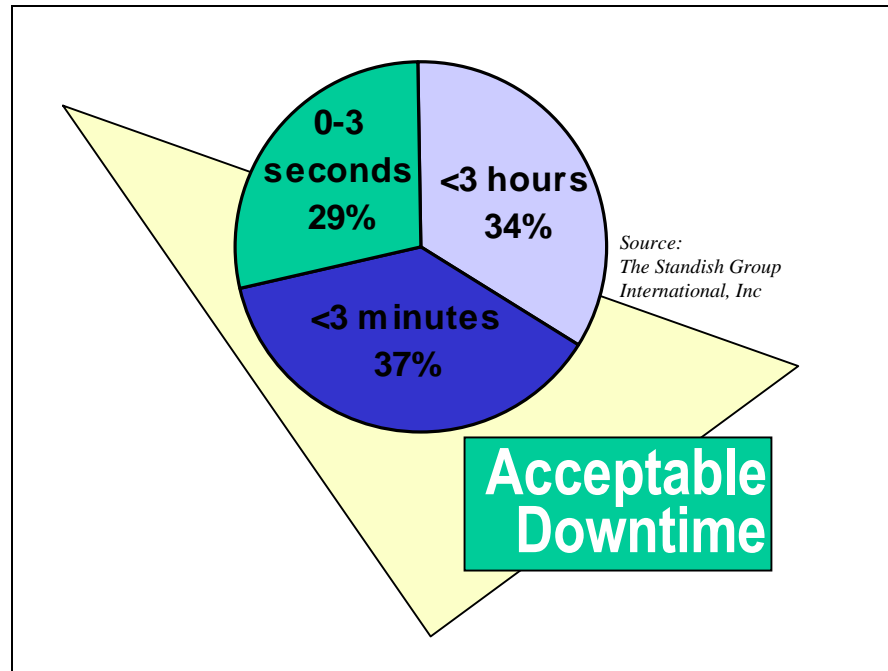


Figure 2: Acceptable downtime is measured in increasingly smaller increments.

This technology brief examines some of the fault tolerance, fault prevention, and rapid recovery measures Compaq has implemented to date. It begins with Pre-Failure Monitoring and Warranty, then moves through the server subsystems to provide an overview of the technologies implemented within the server to eliminate single points of failure and enable rapid recovery, bringing higher reliability to Compaq customers.

SERVER SUBSYSTEMS

Compaq continues to develop and implement technological advances that improve the reliability of server subsystems. Currently available technologies are described below, with references to other white papers for further detail, where applicable.

Processor

Without the Compaq approach to improved reliability, the server would come to an abrupt halt if a processor were to fail. To avoid this potential catastrophe, Compaq starts with top-quality components, then implements a number of redundancy schemes and addresses other factors that can cause processor failure, such as high temperature or an unstable power supply. These safeguards help ensure that fault prevention, fault tolerance, and rapid recovery goals are met.

Off-Line Backup Processor

The Off-Line Backup Processor option, available on the Compaq ProLiant 5000, 6000, 6500, and 7000 (as well as older ProLiant 2000, 4000, and 4500 systems), minimizes downtime caused by processor failure. The system can be configured so that if a processor fails, the system is automatically powered down, reconfigured, and restarted from the second processor with minimal system interruption. The Off-Line Backup Processor can also be used to provide additional processing power during normal operation.

Processor Power Module

A Pentium processor requires tightly controlled power from a dedicated power supply. If a power supply module supporting a processor fails, the system goes down. To prevent that, Compaq servers have three processor power supply modules to support every two processors (two active and one redundant) or, in some models, fully redundant power modules. If one power module fails, the redundant power module takes over operation without interrupting system operation.

Automatic Server Recovery

To minimize the impact of a software, memory, or processor failure, Compaq implements rapid recovery tools in the system management hardware, software, and firmware that are included on all Compaq servers. Two of these tools, Automatic Server Recovery-2 (ASR-2) and Server Health Logs, work together to restore a server to its original state. If an error occurs in a subsystem, ASR-2 will log the error in the Server Health Logs, attempt to restart the system, and take other necessary action to avoid subsequent faults, as specified by the system administrator.

For example, if a processor becomes inoperable or fails the power-up self-test, power to that processor is disconnected and the boot process continues. The other processors continue to run, and an alert message is sent to the system administrator. Replacement of the failed processor can be scheduled to minimize downtime.

I/O Expansion

A number of developments are improving the availability of expansion cards. With the implementation of redundancy and, in some areas, hot plug capability, Compaq servers continue to move closer to the goal of maximum system reliability.

PCI Hot Plug

Compaq leads the industry in developing and delivering PCI Hot Plug technology. Compaq's PCI Hot Plug Adapter technology allows *hot replacement*, which is the replacement of one PCI adapter with an identical adapter while the system is operating. This technology also includes *hot upgrade* (replacement of a PCI adapter with an upgraded adapter) and *hot expansion* (addition of a PCI adapter to an empty slot).

A standard implementation (compliant with PCI SIG guidelines), Compaq's PCI Hot Plug Adapter technology is backward compatible. A PCI Hot Plug Adapter can be installed without using its hot plug functionality until such time as all the requirements (PCI Hot Plug Adapter, a hot plug aware operating system, a user interface, and hot plug device driver support) are in place. This allows a mix of the existing components and the new hot plug technology to be in use at the same time, protecting the substantial investment companies make in network and storage hardware, and allowing a gradual move toward improved system availability in a cost-effective manner.

Intel has licensed the Compaq PCI Hot Plug Controller for use on its system board products.

All industry-standard PCI adapters can be used in Compaq's hot plug environment without modification. However, device drivers require new features to enable use of Compaq servers' hot plug capabilities. Leading independent hardware suppliers committed to modifying their device drivers to be hot plug aware include Adaptec, Dialogic, Digi International, Mylex, Standard Microsystems Corporation, and SysKonnnect. In addition, Compaq is delivering hot plug capable drivers for its own leading PCI server adapters.

Support for PCI Hot Plug technology is being built into current and upcoming versions of Windows NT 5.0, Novell IntranetWare, and SCO UNIX operating systems. For more information about PCI Hot Plug, see technology briefs 398A/1196, *PCI Hot Plug Technology*; ECG004.0897, *PCI Hot Plug Technology with SCO Software Architecture*; 064A/0797, *Deploying PCI Hot Plug in a Microsoft Windows NT Environment*, and 131A/0397, *PCI Hot Plug Technology with Novell Architecture*.

Network Interface Controller (NIC)

All Compaq network device drivers have integrated error recovery features that allow the drivers to detect failure events and recover from these errors. The drivers can reset the NIC and continue running, usually without noticeable interruption, after the following types of errors:

- Adapter check interrupt: When the hardware detects a problem, a detailed console error message is generated and an immediate attempt to recover begins.
- Link status change: Link status changes occur when a cable is unplugged or there is a hub problem. If a fatal link status change occurs, the driver attempts to recover from it.
- Transmit integrity check failure: If the driver receives indication that the interface integrity is compromised (by a cable or hub failure, for example), it reports the failure and attempts to recover.

Compaq servers can be configured to take advantage of the latest redundant NIC technology, a reliability feature unique to Compaq in this class of servers. Under Windows NT 4.0, Novell IntranetWare, and SCO UNIX, NICs can be installed in redundant controller pairs, sharing a driver (Figure 3).

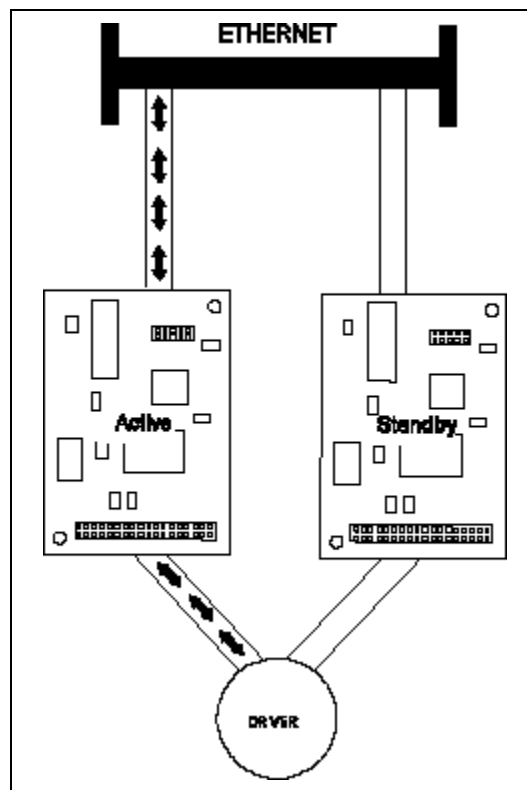


Figure 3: NICs in a redundant controller pair, sharing one device driver.

When the device driver detects an error on the NIC and cannot effect recovery, the driver switches the roles of the active and standby interfaces (standby becomes active) without interruption of service, allowing conveniently scheduled replacement of the failed controller. In systems with hot plug capability, the failed NIC can be replaced without shutting down the system.

I/O Voltage Regulator Module

To help ensure a consistently regulated power supply to the I/O boards, Compaq provides two voltage regulator modules per I/O board. The modules monitor one another. If one module fails, the other takes over, and the system administrator is notified through Compaq Insight Manager.

Memory

Compaq includes ECC memory in its servers to provide protection from memory errors in main system memory. The ECC memory scheme delivers superior error detection and correction capabilities, providing a greater level of data integrity for all network environments.

ECC memory detects single and double-bit errors, and corrects single-bit errors. In Compaq servers, ECC errors are logged to the Server Health Log, where they are stored in non-volatile RAM that can be accessed by system administrators to help identify the cause of the errors and determine how best to correct the situation. Compaq Insight Manager can access and display Server Health Log information from remote consoles or via modem. For more information about ECC Memory, refer to white papers 100A/0395, *ECC Memory* and 618A/0796, *Why Buy Compaq Memory?*

Primary and Secondary Storage

Complex software, increasing dependence on business-critical data, shrinking backup windows — these factors make reliable primary and secondary storage systems essential. Compaq offers a number of ways to prevent storage failure and allow rapid recovery if failure does occur.

Hard Disk Drive

Compaq offers a variety of rigorously tested disk drives in hot pluggable and non-hot pluggable models. Compaq's industry leading qualification and testing process lowers the risk of disk drive down time by ensuring that the quality and performance of these hard drives is best-in-class and optimized for demanding server environments. Audit tests are performed in a realistic environment, with drives connected to intelligent controllers and mixed with other drives. Different combinations of hardware, configurations, and applications are tested. The test program includes controller fault tolerance testing, in which drive failures and power failures are artificially induced.

Integration of Compaq drives with Compaq's array controllers provides leading fault tolerance and management, further minimizing system downtime. The ProLiant 2500, 5000, 6000, 6500, and 7000 servers feature hot plug disk drives, which can be removed and replaced without shutting down the system.

Compaq drives are covered by the Pre-Failure Warranty. As part of that coverage, Compaq Insight Manager constantly monitors hard drive and tape drive status, and proactively alerts system administrators to early problem indicators before an actual fault occurs. For more information about Compaq disk drives, see technology brief ECG026.0997, *Why Buy Compaq Drives?*

Duplex Backplane

On the ProLiant 6500 (and ProLiant external storage units), a duplex (or divided) backplane allows connection of two SCSI drive controllers to one backplane, so two drives or drive arrays can mirror data storage. This is a cost-effective improvement in data protection and availability.

Disk Drive Array

Increasingly complex network applications, migration of business-critical data to servers, consolidation of servers to centralize network management, and higher efficiency expectations create new data storage requirements. These requirements include capacity growth, data availability, high performance, and manageability, all of which can be provided by a disk drive array.

Compaq pioneered mainstream server disk drive arrays, and Compaq arrays are now in the seventh generation. The latest models include powerful troubleshooting features to help predict and prevent drive failure. Drive Parameter Tracking monitors drives and notifies the system administrator of potential problems, while Dynamic Sector Repairing scans hard disk drives for bad sectors and remaps the drives when necessary. In addition, ECC technology protects data in cache DRAM. This provides greater protection than mirroring and is more cost-effective.

With fault tolerance enabled, SMART-2 Array Controllers keep systems online and accessible after a drive failure and provide automatic recovery with online sparing. Hot plug drives can be replaced without powering the system down. In addition, the SMART-2 Array Controllers support redundant array of independent disks (RAID) architecture. RAID is a way of storing data across multiple drives in redundant configurations or with data striping and parity checking. The On-line Capacity Expansion feature of the SMART-2 Array Controller allows server storage capacity to be expanded without taking the server down. Prior to this innovation, expanding storage capacity attached to an array controller required a time-consuming backup/reconfigure/restore cycle.

Performance, configuration, and fault management are provided by Compaq Insight Manager and SMART-2 Array Controllers are covered by the Compaq Pre-Failure Warranty. For more information about the SMART-2 Array Controller, see technology brief 317A/0797, *Compaq SMART-2 Array Controller Technology*.

Online Storage Controller Recovery Option

Compaq Online Storage Controller Recovery Option eliminates a potential single point of failure in RAID arrays connected to a single controller by mating two SMART-2 Array Controllers as a controller pair. This combination of hardware and software, developed by Compaq, sits idle in the background under Windows NT and provides failover protection for pairs of SCSI controllers. One controller is active, while the other remains in standby mode. If the active controller fails, the Online Storage Controller Recovery Option switches traffic to the standby controller without loss of data (Figure 4).

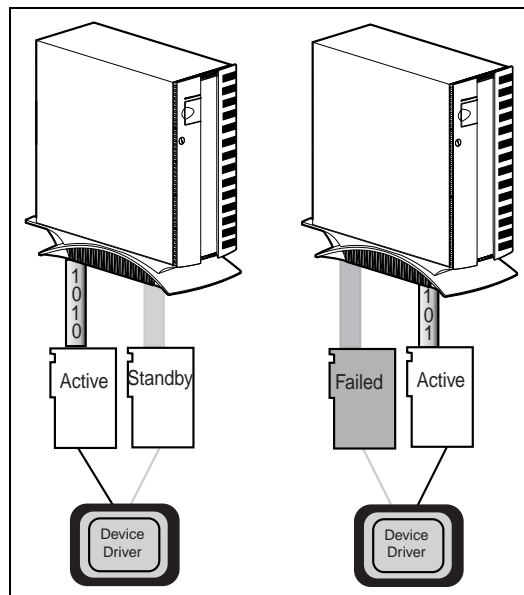


Figure 4: The controller pair is established. If the active controller fails, the standby controller is promoted to active.

The Online Storage Controller Recovery Option is a natural partner to the PCI Hot Plug technology: System service continues uninterrupted after the failover, and the failed controller can be replaced without shutting the system down. This option is supported for single bus versions of ProLiant Storage System/U units in tower and rack-mount configurations. For more information about the Online Storage Controller Recovery Option, refer to white paper 066A/0797, *Implementing Online Storage Controller Recovery Option Under Windows NT*.

Fibre Channel

For greater reliability and fault tolerance, Compaq is developing a number of products that will implement Fibre Channel technology. Fibre Channel is a key technology for the system-to-storage interconnect (high-speed box-to-box communications) and the serial drive interface (high-performance disk systems) in delivering bigger, faster, better network data storage solutions. It provides opportunity for the integration of primary and secondary storage as well as shared storage between multiple servers.

Developed by committees accredited by the American National Standards Institute to define new protocols for flexible information transfer, Fibre Channel is an industry-standard interconnect and high-performance serial I/O protocol that is media independent and supports simultaneous transfer of many different protocols. The use of fiber optics for transmission results in extremely low error rates. Furthermore, Fibre Channel incorporates a powerful encoding scheme and a strong cyclic redundancy check on each message frame, ensuring data integrity.

Fibre Channel is now the only standard that can handle the traditional channel and network functions simultaneously on the same port. It supports simultaneous hot plug, allowing removal or insertion of multiple drives from an active loop without affecting throughput. For more information about Fibre Channel, refer to technology brief ECG008.0897, *Strategic Direction for Compaq Fibre-Channel-Attached Storage*.

Tape Drive

Compaq's DLT drives use advanced linear recording technology, a highly accurate tape guide system, and an adaptive control mechanism to provide high-capacity, high-duty cycle backups. The drives have four parallel tracks and heads; if one track/head unit fails, the others can continue the backup. Up to three track/head units can fail without putting a drive out of operation.

A powerful Reed Solomon ECC featuring a 64-bit cyclical redundancy check on each 4 KB of media data, end-to-end 16-bit cyclical redundancy check on each record overlapped with parity from the SCSI bus, and internal parity checking on the cache buffer are used to help ensure data integrity. This results in a theoretical average hard error rate of only one in 10^{17} bits, with less than one undetected error in 10^{30} bits of data. As an added reliability measure, Compaq DLT drives verify data by performing a read operation after each write command and by automatically re-recording data if a recording error is detected.

The Tape Drive Status Alert feature notifies the system administrator, through Compaq Insight Manager, if something goes wrong in preparation for a backup. The Reread/Rewrite Threshold Alert feature notifies the system administrator if predetermined reread/rewrite levels are exceeded, preventing drive failure from extreme reread/rewrite activity. For more information about Compaq DLT drives, see technology brief 395A/0197, *DLT Hardware Technology*.

DLT Array

Compaq DLT Arrays help protect critical data through regular automated backups of large servers, networks, and enterprises in a process that maintains the absolute integrity of the data. The DLT Array houses up to four DLT drives (driven by Cheyenne ARCserve 6.0 or JETserve 3.3), which enable fast image backups in redundant array of independent tapes (RAIT) configurations (similar to disk drive RAID configurations). Backup applications that do not support RAIT configurations, such as Seagate Backup Exec and Legato Networker, can also be run with Compaq DLT Arrays.

When used in RAIT configuration, the DLT Array stripes data across the drives and creates parity records, which can be used to rebuild data on a failed tape/drive. If one drive goes down during a backup, the others continue — as many as three drives can fail without compromising the backup. Drive repair or replacement can be scheduled when the backup is complete.

Tape manageability features are included in Compaq Insight Manager. The DLT Array is covered by Compaq's Pre-Failure Warranty. For more on the DLT Array, see technology brief 395A/0197, *DLT Hardware Technology*.

DLT Tape Library

The Compaq DLT Library (Figure 5) provides unattended, automated backup. It has a cable management arm to prevent cable crimping or loss; high-capacity fans for significant cooling headroom, even for future higher speed drives; the ability to detect contaminated heads and notify the system administrator; a robotic mechanism and face plate of Teflon-impregnated polycarbonate to reduce drive and cartridge wear while minimizing the chance of contaminating the cartridge in the drive; and drive redundancy capabilities, with online drive replacement to eliminate downtime.

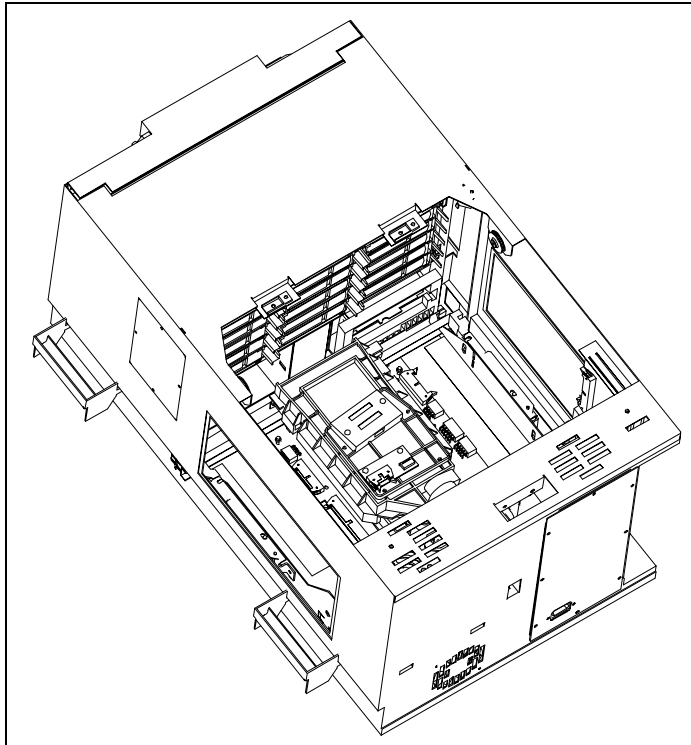


Figure 5: Interior view of the DLT Library showing the robot and magazines with tapes.

For more information about the Compaq DLT Library, see technology brief 272A/0797, *Compaq DLT Library Technology*.

Power

Compaq's power supply and power management technologies implement the latest developments to help ensure consistent, properly regulated power to the server — and to help prevent data loss in the event of a complete external power failure. The design and testing phases of power supply development include rigorous testing to help ensure superior performance.

Internal Power Supply

On the Compaq ProLiant 6000, 6500, and 7000 servers, power supplies can be arranged in an $n+1$ configuration, where n equals the number of power supplies required to run the system. Power supplies share the load; one can fail without a loss of power to all components.

With $n+1$ redundancy of hot plug power supplies, a system can quickly be brought back to a redundant configuration, without having been shut down. The power rails and control signals are isolated: In 98 percent of hot plug power supply failure events, other power supplies are not affected by the failure of one.

Compaq Insight Manager provides detailed monitoring of the hot plug power supplies, gathering and analyzing information on many factors affecting power supply performance. Increased power capacity is recommended when necessary.

Intelligent Power Supply

Demand for more informative status/health information, more automation, and increased reliability of power supplies continues to rise. In response to that demand, Compaq developed the intelligent power supply with an embedded microcontroller and a special bus.

Enhanced communication with the host system allows the intelligent power supply to provide more detailed status information than was previously possible. This increased communication, which provides status messages and alerts through Compaq Insight Manager or the Windows NT Performance Monitor, allows the system administrator to troubleshoot more effectively when problems arise and, in some cases, prevent problems or downtime from occurring.

Fault tolerance features include:

- Over current monitoring.
- Over voltage monitoring.
- Fan failure monitoring.
- Power supply crowbar.
- Maximum allowable temperature status reporting.

The microcontroller can also be configured in one of three modes for graceful shutdown:

- Secure — Power supply will not shut down if power switch is flipped.
- Delay — Power supply will shut down after a 10-second delay. This allows time to reactivate the switch if it was mistakenly flipped.
- Graceful shut-down — Power supply will shut down after all running applications have properly closed.

Compaq's intelligent power supply can be used redundantly and is hot pluggable; when it is installed redundantly in hot plug power supply capable servers, failover is automatic. The failed unit can be replaced, and the new unit will power up automatically, without taking the system down.

Compaq introduced the intelligent power supply in three high-end servers, the ProLiant 6000, 6500, and 7000, as well as the ProLiant Storage System. For more information about the Intelligent Power Supply, see technology brief ECG025.0897, *Intelligent Power Supply*.

Uninterruptable Power Supply (UPS)

The Compaq UPS provides temporary power to the server in the event of a power interruption and prevents the loss of critical data by allowing the server to be gracefully shut down. Its Enhanced Battery Management feature prolongs the life of the battery while monitoring the battery's charge level to identify when it needs to be replaced. If there is a power failure when the battery charge is below an acceptable level, the server will close open files, log off users, and gracefully shut the system down. For more information about the Compaq UPS, see white paper 254A/0396, *Compaq UPS Support in SAP R/3 Platforms*.

Cooling

Server fans speed up as the temperature rises and alert the operating system through Compaq Insight Manager if the temperature approaches a critical point. Fans are available in hot-pluggable, redundant pairs as an option on the ProLiant 6000, and standard on the ProLiant 6500 and 7000. Like other hot plug components, these fans can be individually powered down and replaced in the event of a failure, while the redundant fan of the pair takes over. This helps ensure that a fan failure will not take the server down.

MANAGEMENT

Compaq offers hardware- and operating system-independent server management tools (hardware, firmware, and software) that help system administrators prevent system failure or, when failure does occur, identify the cause and effect a rapid recovery. These tools integrate with leading network management applications.

Integrated Remote Console

Integrated Remote Console's combination of hardware and firmware is integrated into the server motherboard. This makes seamless remote console, remote reset, and reset sequence replay features available whether servers are in multiple remote locations or grouped in a centralized site away from the system administrator — and regardless of whether the server operating system is online or offline.

A server can be accessed in different ways, depending on connection method and server state. A server can be connected to other computers through an in-band connection or an out-of-band connection. An in-band connection is the typical communications channel for server information and data, while an out-of-band connection is a separate, dedicated communications path for management data. An online server refers to one in which the operating system is up and running. If the operating system is down, the server is offline.

The remote console application redirects video from the remotely-managed server to an off-site system administrator console, providing full text mode video and keyboard access. Should a remote server need to be reset, the system administrator can perform the reset quickly. The Integrated Remote Console works through Compaq Insight Manager, and its capabilities can be expanded with the addition of the optional Remote Insight Board. For more information about the Integrated Remote Console, please refer to white paper 582A/1096, *Remote Server Management with Integrated Remote Console*.

Remote Insight Board

The Compaq Remote Insight Board provides distributed enterprise companies (with computer resources at a number of end-user locations) an effective, host-independent remote server management tool with the following features and capabilities:

- Complete hardware independence from the managed server, including an on-board modem that provides out-of-band network communication.
 - Remote Insight Console Application, a software tool that resides on the Remote Insight board, providing access to and control of the managed server at all times, regardless of server location, server condition, or system administrator location. Features within Remote Insight Console Application provide viewing and control of all phases of server operation and full capability to reset the server remotely, without any loss of connection, regardless of server condition.
 - Critical information and troubleshooting data capture.
 - Immediate alerting for quick response to protect business-critical data and applications.
 - Full battery backup on the board to prevent failure due to server power outage.
 - Variable user access rights, unauthorized user detection, and communications security for flexibility and an extra measure of protection.

For more information about Compaq Remote Insight, see white paper 078A/0496, *Compaq Remote Insight Product Overview*.

Pre-Failure Monitoring and Warranty

The Pre-Failure Warranty extends the advantage of a Compaq three-year, limited warranty to critical components before they actually fail. The Pre-Failure Warranty is standard on all Compaq servers using Compaq Insight Manager 2.0 or later; it applies to Error Checking and Correcting (ECC) memory, Pentium Pro and Pentium II processors, server hard drives (including the Compaq IDA, IDA-2, and SMART Wide-Ultra SCSI-3 drives) and any Compaq drives attached to array controllers, as well as SMART SCSI Array Controllers. Sophisticated system management tools can identify degraded or failing components before errors occur and alert the system administrator.

Compaq servers use health logs to report failure or potential failure conditions. The monitoring software supports health features for these components: real-time clock, Peripheral Component Interconnect (PCI) or Expanded Industry Standard Architecture (EISA) bus, how long the hardware has been in use, Automatic Server Recovery, power modules, fans, and temperature. Health drivers are available for Microsoft Windows NT, Novell IntranetWare, SCO UNIX, and IBM OS/2 operating systems.

Pre-failure events are reported through Compaq Insight Manager, a robust server management tool that provides intelligent monitoring and alerting (based on more than 1,000 parameters), remote maintenance, and visual control of servers in a network environment. Compaq Insight Manager is standard on all Compaq ProSignia and ProLiant servers. Insight management agents provide information to Compaq Insight Manager and generate alarm notifications for the system administrator if significant changes occur in the fault prevention or performance aspects of system operation. When Compaq Insight Manager indicates that a critical server component may fail, the component is replaced free of charge under the warranty, even though it still may be operational. For more information about Compaq Insight Manager, see white paper 170A/0696, *Compaq Insight Manager*. For more information on the Compaq Pre-Failure Warranty, see white paper 370A/0797, *Pre-Failure Warranty for Compaq Servers*.

Servicing

Compaq server chassis designs include tool-free access and board release levers for all internal components, which allow quick access for rapid recovery should replacement of a part be required.

CONCLUSION

Compaq consistently takes a leadership role in the development of new technologies that establish additional fault prevention, fault tolerance, and rapid recovery capabilities in industry standard server system components. By designing its servers with these improved subsystems, Compaq meets the increasing reliability and rapid recovery needs of today's enterprise systems.

Compaq maintains a commitment to solutions based on open industry standards, challenging expensive, RISC-based proprietary server systems. The result: affordable, reliable systems with fewer single points of failure and improved rapid recovery capabilities.