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A Server Consolidation Solution

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Project Paper Revision/Change History Tracking

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1	Shari Plantz-Masters	Oct. 24, 05	Initial submission
2	Shari Plantz-Masters	Nov. 11, 05	1) Corrected Grammar & APA format. 2) Refined explanation of methodology and project examples in Chapters 2 & 3. 3) Better defined requirements in chapter 1.
3	Shari Plantz-Masters	Dec. 18, 05	Restructured Abstract to better reflect paper

Abstract

Advances in server architecture has enabled corporations the ability to strategically redesign their data centers in order to realign the system infrastructure to business needs. The architectural design of physically and logically consolidating servers into fewer and smaller hardware platforms can reduce data center overhead costs, while adding quality of service.

In order for the organization to take advantage of the architectural opportunity a server consolidation project was proposed that utilized blade technology coupled with the virtualization of servers. Physical consolidation reduced the data center facility requirements, while server virtualization reduced the number of required hardware platforms.

With the constant threat of outsourcing, coupled with the explosive growth of the organization, the IT managers were challenged to provide increased system services and functionality to a larger user community, while maintaining the same head count. A means of reducing overhead costs associated with the in-house data center was to reduce the required facility and hardware resources. The reduction in the data center footprint required less real estate, electricity, fire suppression infrastructure, and HVAC utilities. In addition, since the numerous stand alone servers were consolidated onto a standard platform system administration became more agile to business opportunities.

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Chapter One: Introduction

1.1 Problem Statement

In November 2004, Denver metro area voters approved the expansion of the city transit authority's Light Rail system from two corridors to eight corridors, which included the expansion of existing rail lines. Although the approval demonstrated the popularity of the mass transit solution, the magnitude of the project would be the largest undertaking in the history of the Denver transit authority.

Rapid expansion of IT services placed large demands on the support infrastructure for the organization. The main data center that serviced the entire organization was aging and could not accommodate the massive needs of the Light Rail project, in addition to other projects such as a new Enterprise Resource Planning (ERP) system. The relevance of the ERP project was that the new system would replace all business support functions, including Finance, Accounting, Human Resources, Inventory, and Maintenance Management.

The inadequacy of the data center prompted the migration of several critical systems to alternate hardware and operating systems. In addition to updating the infrastructure, the Information Technology (IT) department was tasked with designing and implementing a project office for the multi-billion dollar Light Rail project, known as FasTracks.

IT management was confronted with the need to provide increased system services and functionality to a larger user community while maintaining the same head count. Therefore, a new system infrastructure needed to be introduced that met the requirements of upper management by reducing Total Cost of Ownership (TCO), maintaining of staff head count, and adding service value to the organization.

The goals of the server consolidation project that became important to upper management was the project potential of realigning IT services with that of business functions. The realignment had numerous benefits including increased service quality and response, lowering TCO, short and long term ROI, and the introduction of a resilient systems network for disaster recovery efforts.

To attain the goals of upper management and to survive the explosive growth of the organization, the server administration team needed to redesign the system infrastructure for overall physical and logical efficiencies with new system technologies. The server consolidation project employed a waterfall methodology that followed the full spectrum of the System Development Life Cycle (SDLC), including research, analysis, and design (Burn, 2002). Industry standards, set by the Project Management Institute (PMI), for project management were also exercised throughout the project in order to produce a quality product within the allocated budget and time frame.

1.2 Existing Infrastructure

The main data center, located at the operations facility, consisted of antiquated system hardware and operating systems. Two years prior to the server consolidation projects' beginning, a storage centralization project was completed which produced a Fibre Channel based SAN array, consisting of two terabytes. The server hardware consisted of Compaq Alpha servers, first generation Intel based HP Proliants and

Prosignias. The operating systems that resided on the server hardware included: Tru64 UNIX, VMS, Windows NT, and Windows 2000.

The data center was comprised of sixty-four varied server hardware platforms, which in the absence of system management software, made the environment difficult to operate. The situation of non-standard equipment and lack of management software led to a high risk of major failures. Forty-two of the servers ranged from four to ten years old, which was near or beyond the five year guideline for technology replacement, See Appendix C: Server List.

1.3 Project Goals and Requirements

A means of reducing overhead costs associated with in-house data centers was to reduce the required facility resources though server consolidation. An additional benefit of the project would address the importance of administration efficiencies by maintaining staff head count, while accommodating added system responsibilities.

The IT department was committed to improving service delivery to its users. To gauge organizational performance, the department utilized the Capability Maturity Model (CMM) developed by Carnegie Mellon. The objective of the project was to produce an efficient system infrastructure that met CMM level-4 standards

The CMM model was modified to better fit the data center objectives, instead of the model's original purpose of software development. Prior to the project, the main data center functioned at a combination of levels 2 and 3, with an objective of obtaining level-4 functionality, See figure 1.

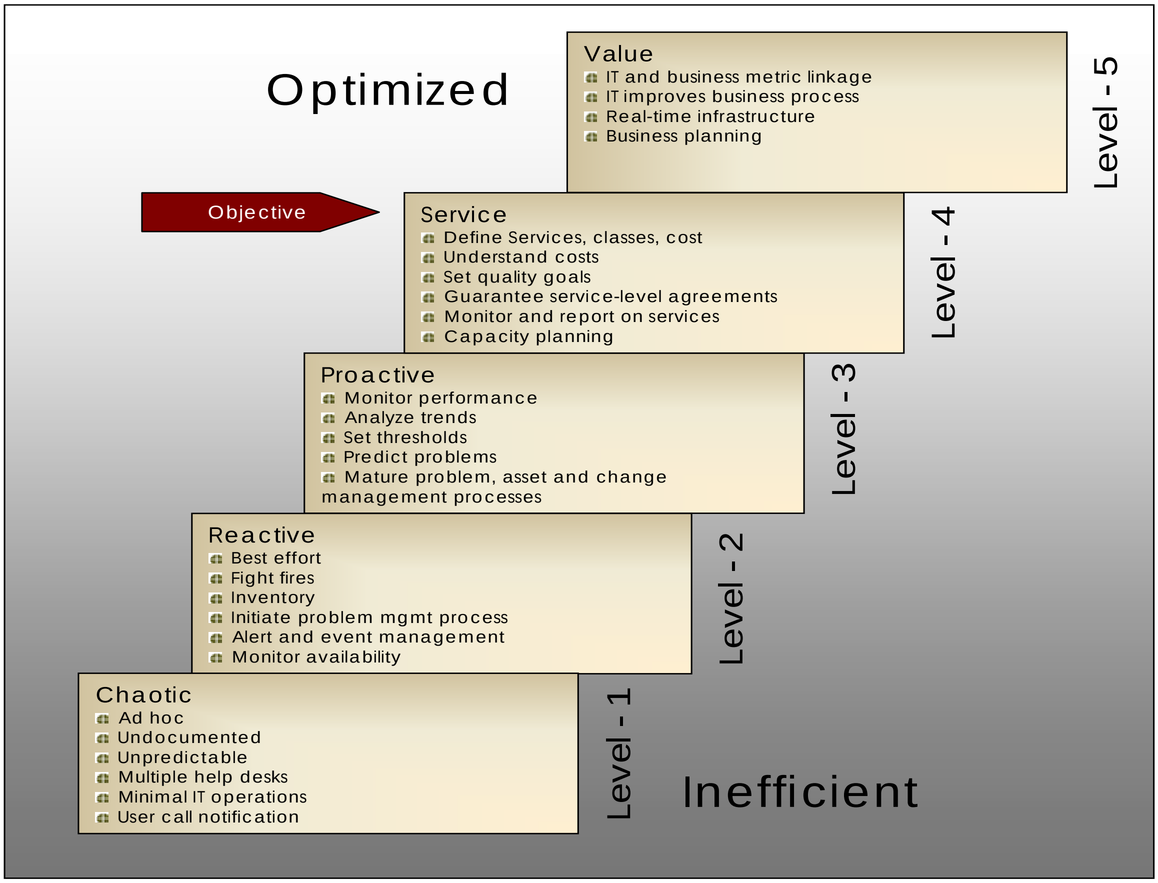

Figure 1: IT Management Process Maturity Model (Curtis, 2005)

A key benefit of setting the aggressive level-4 objective was that predictability, effectiveness, and control of the organization's processes and services would improve as the organization moved up each level.

The IT department evaluated alternative data center architecture, systems, and processes in order to accommodate demands pertaining to FasTracks, the ERP, and disaster recovery. The findings of the evaluations suggested that the various aspects involved with the server consolidation project would likely address key requirements of the other projects stated above.

The numerous hardware platforms that have infiltrated the organization's data center required an unacceptable amount of floor space. A means to address the issues surrounding the facility requirements of the data center was to consolidate or miniaturize the required hardware platforms.

The project was further complemented by the use of server virtualization software in order to run multiple virtual servers on a single blade platform. The technologies addressed the on-going issue of various Windows based applications requiring their own server hardware platform. The use of virtual servers significantly reduced the number of required Intel based hardware platforms.

Therefore, the goal of the server consolidation project was to address the large overhead costs and resources associated with the Intel/Windows infrastructure. Blade servers and server virtualization software technologies were employed to reduce TCO.

The proposed system infrastructure utilized blade technology coupled with the virtualization of servers. In doing so, the data center footprint was dramatically reduced. Also, server virtualization reduced the number of required hardware platforms, which led to greater efficiencies and lower cost of ownership. The target ratio of virtualized servers to physical platforms was a range of three to eight logical instances to one physical instance, depending on the required resources. A requirement of the proposed consolidation project was to migrate at least 12 servers to the new blade infrastructure. The phase-in approach would form a sound foundation for the introduction of new consolidation technology without undue risks, such as service outages. The initial migration dealt with selected servers that had less visibility to the user community, in the event of an unplanned service outage.

Furthermore, the overall effort to reduce TCO required the proper utilization of system management software (Wright, 2004). The blade servers came with robust server management software that allowed blades and virtual servers to be provisioned or re-provisioned dynamically. Thus, the entire software contents handled by a set of blades could be changed as the workload evolved. The virtual servers also provided a type of image management that was available as a plug-in module to the blade management software, which enabled central management of the entire system architecture.

Through the management software, an image (operating system and applications) of a virtual or physical server could be saved to a file and then used to provision the same server instance or other similar server platforms. The provisioning capability could drive dynamic resource allocation, disaster recovery measures, or be used as a software distribution solution. The blades and virtual servers were capable of being centrally controlled through the server management software.

The rapid growth of IT responsibilities, coupled with an antiquated data center presented a strong burden on staffing resources. The system administration staff consisted of a lead and four administrators to support the main data center and a secondary data center. The secondary data center, which would eventually double as a disaster recovery site, was located at the FasTracks project office.

The standardization of the server hardware platform and utilization of system management software allowed the server staff the ability to manage a larger infrastructure with the same head count. Likewise, the physical consolidation and reduction of actual server hardware would reduce associated hardware maintenance agreements and facility resources, such as: floor space, cooling, and electricity.

1.4 Project Scope

The Denver transit authority had a unique opportunity to capture synergy from a number of concurrent activities:

- FasTracks mobilization and the accompanying project office.
- Integration and deployment of a new ERP system.
- The development of an off-site disaster recovery facility.
- The relocation and upgrade, including a new CAD/AVL system, for the Disabilities Transit call/dispatch center to the project office building.
- The continued upgrade to the District's core server infrastructure.

The main data center utilization of servers had grown to over sixty individual hardware platforms, encompassing a variety of server models that supported key elements of operations. As previously architected and deployed, each server required extensive manual intervention to maintain and operate.

The majority of transit authorities were moving their industry specific applications from a two-tier (mainframe) architecture to a three-tier (client/server) architecture, which included desktop, application, and database servers. The consolidation project focused on the required server infrastructure for the Application and Database tiers, See figure 2.

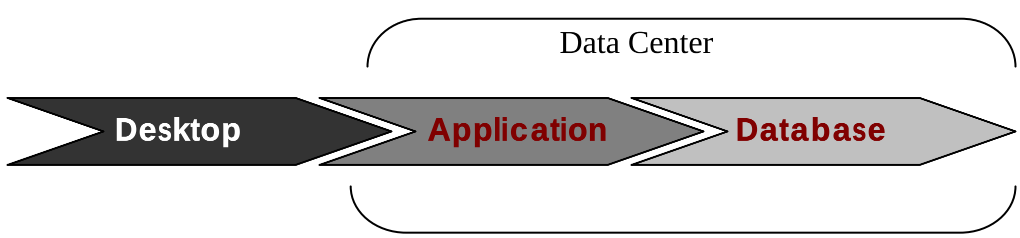

Figure 2: Three-Tier Architecture

The general and architecture requirements for the consolidation project dealt with high level departmental and low level technical needs, as follows:

- Server Upgrades
    - Reduce the total number of physical servers
    - Reduce the cumulative maintenance requirements
    - Automate server administration
    - Introduce a seamless central system administration solution
- Standardization
    - Define and implement standard processes
    - Create reliable and consistent server configurations
    - Standardize server hardware
- Compliance
    - Detect and resolve configuration change problems
    - Proactively manage software updates to minimize security risks
    - Aggregate data across the environment in real-time
    - Improve data restore times
    - Control automation
    - Optimize use of system administrators time
    - Quickly deploy, repurpose, recover servers
- Optimization
    - Eliminate underutilized and legacy servers
    - Identify usage thresholds/patterns

- Improve mean time to repair
- Recover from an unexpected configuration error
- Automate corrective actions based on events
- Track non-compliant events

- Integration
  - Consolidate management across environment
  - Improve manageability and simplify training

There are a number of factors that suggested that the department should consolidate the sixty-four servers into a more orchestrated architecture. This was driven by the opportunity to capture:

- Hardware
  - Reduction in costs
  - Implement effective, large-scale backups
  - Implement on-demand shared storage
  - Increased effective use of physical server hardware
  - Implement common system management software
- Operations
  - Lower power consumption
  - Reduction in space requirements
  - Reduced complexity
  - Improved scalability

- Easier disaster recovery planning
- Improved system security
- Optimize administrative operations and associated staffing

1.5 Benefits and Risks

In recent years, advances in server architecture have enabled corporations the ability of reducing the size of data centers while gaining added performance and services (Enck, 2004). The reduction in data center overhead costs by physically and logically consolidating servers into fewer and smaller hardware platforms can have the potential to realign IT services with business needs.

The realignment for the organization would through the reduction of overhead costs for server hardware, facility resources, and labor. In doing so, the IT department would have the means of moving from a cost center to more of a service center by continually adding value to the organization. System management software would play a critical role in the success of the realignment by allowing the server team to centrally control the entire server infrastructure, both locally and remotely (Wright, 2004).

The proposed solution promised several benefits for the organization that were favorable to upper management. However, the risks associated with the project had to be noted by the server team and dealt with accordingly. The general benefits and risks for the project were as follows:

- Benefits
    - Fast deployment
    - Simple fail-over

    - Fast repair
    - Administrative agility
    - Simplified physical infrastructure
    - Facility and labor cost reductions
- Risks
    - A need to develop standards and processes
    - Power/cooling issues with new architecture
    - Lack of management software
    - Software costs for proposed solution
    - Immature consolidation technology
    - Concerns for single points of architectural failure
    - System update versioning problems across servers
    - Middleware compatibility problems
    - Operating systems and middleware dependencies

A means of reducing overhead costs associated with in-house data centers was to reduce the required facility resources though server consolidation. Reducing the data center footprint requirements equated to reduced real estate, power, lighting, fire suppression infrastructure, and HVAC services. In addition, since the numerous stand-alone servers were consolidated into one or two blade server enclosures system administration became more efficient by standardizing the platforms. In doing so, the management of the hardware was similar for each server, enabling processes to be simplified and consistent.

The conditions pertaining to multiple dissimilar servers were unmanageable and did not provide a viable solution for future demands. Further, the legacy hardware and Operating Systems had reached end-of-life and were no longer supported by the manufacturer.

During an outside IT assessment conducted in 2002, the TCO analysis identified that the organization regularly under-spent in maintaining the IT infrastructure. At the time of the study, the transit authority annually invested approximately $482,000 for general operating costs (e.g. labor) compared to a transportation industry average for a comparable organization of $2,500,000. The deferred costs of the past years had put the organization’s data center at high risk of an inevitable service outage due to antiquated resources and processes.

The short term strategy of spending less on the infrastructure was favorable to senior management because the financial numbers showed that the department annually operated under budget, resulting in savings for the organization. However, the strategy eventually led to a server/network infrastructure that was severely out-dated and required a significant amount of financial and labor resources to bring the environment up to current hardware/software standards. Several key servers were running on hardware and operating systems that were retired by the manufacturer. Out of the sixty-four production servers forty-two were four plus years old. Twenty-three of those servers were over five years old and had been placed on the manufacturer’s retirement list; refer to the server list in Appendix C.

The complexities of the server infrastructure presented multiple system points of potential failure and significant complications in general administration, maintenance and operations. In the absence of an enterprise system management solution, the server administration staff had to perform daily checkups of each server and try to determine if any one of the systems dependent on that server were experiencing problems. Commonly, the team would be informed of a problem by the user community after the service outage had occurred. The payroll system, in particular, experienced weekly issues due to the numerous server dependencies, See figure 3.

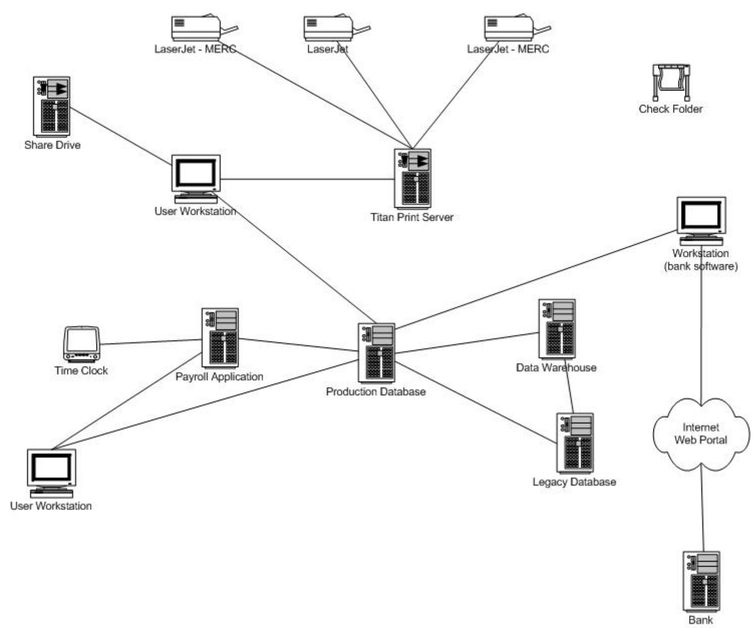

Figure 3: Payroll System

The payroll system was complex and spanned numerous server platforms. An advantage to the complexity of the system was that the required information for a payroll check did not permanently reside on one particular server. On the other hand, this integrated security advantage created numerous dependencies and points of failure which the server team was unable to proactively correct because of the inability to manage systems, only servers, See Appendix B: Network System Diagrams.

During research the realization was made that throughout the technology world, there was a movement to consolidate servers in data centers to reduce TCO and to better manage the infrastructure, such as: security, availability, and disaster recovery (Phelps, March 31 2005). However, Gartner Group identified a risk to the TCO strategy that was associated with the anticipated savings in staffing and to a lesser degree hardware. A survey of consolidation efforts showed that sixty percent of organizations reported cost savings, but only twenty-five percent had shown reductions in staffing (Phelps, March 1 2005). Approximately sixty to seventy percent of server life-cycle costs are associated with administration of server management tasks, such as: server deployment, maintenance, tuning, platform migration, upgrades and reconfiguration.

The organization employed four full time staff members and one consultant to support the main data center. If the consolidation project was not properly executed and streamlined to fit business functions, then two additional server administrators would potentially be needed to address the secondary data center, the ERP, legacy operations, Disaster Recovery, and other associated projects (Bittman, 2004).

Based on the old server architecture and the manual processes required to administer the infrastructure the server re-architecture was performed in order to accommodate additional server platforms for near future projects. The ERP, FasTracks, and Disaster Recovery would be adding as many as twenty additional servers and a duplicate SAN unit located at the project office. This was a sixty-six percent increase in server infrastructure needing to be supported with the same staff head count.

Therefore, in addition to standardizing the system platforms, integrated virtual server management software was used for imaging and deploying server software platforms for production and Disaster Recovery agility. The selected products were required to have the ability to image firmware/RAID microcode and to migrate those images to similar hardware. The importance of capturing the firmware/RAID microcode of the server was crucial to data protection and recovery time.

There are two areas to consider when protecting data residing on disk: file corruption/deletion and hardware failure. File protection is commonly addressed through a data backup solution to tape. Protection of hardware failure is common and focuses on the moving parts of a server, such as: hard drives and fans. Data loss from failed hard drives is commonly addressed with RAID. Redundant array of inexpensive disks (RAID) is a set of disk drives whose input/output (I/O) activity is managed by an external-based or host-based RAID technology in the form of a RAID controller. By incorporating RAID, data is written to multiple disks with no one disk being a single point of failure. RAID technology is also important in protecting the Operating System and applications (Cox, 2003).

The common server build for the organization was to have two local hard drives with identical data residing on both hard drives, known as RAID 1 or mirroring. These local drives would house the Operating System and applications. The back-end SAN unit, storing the organizational data, would also incorporate the strategy of writing data across multiple disks (RAID 5) so that in the event of two simultaneous drive failures, the failure would be completely transparent to the end-users.

The use of virtualized servers was to address the consolidation of current hardware platforms. Even though the same amount of operating systems and accompanying licenses still existed, the amount of required hardware platforms was reduced. The server virtualization solution addressed hardware overhead costs. However, the issue of the number of individual servers whether physical or virtual, still existed and needed to be managed by the same server staff head count. Therefore, enterprise server management software was introduced in order to streamline and centrally manage the system infrastructure by automating various tasks, such as: software updates, server deployment, proactive maintenance, hardware/software auditing, and asset tracking. The selected management software was also capable of managing/monitoring server hardware, images, and alarms. The automation of system administration tasks would have a direct impact on reducing labor costs by increasing efficiencies for time management and curbing labor costs (Bittman, 2004).

Chapter Two: Information Research & Review

2.1.0 Research Methodology

The method for the information gathering phase of the project was used as a means to fill the analysis gap between technologies and the current skill set of the server administration staff. The emphasis of the research was to introduce new concepts and processes to further the movement to a storage centric data center, which was an overall strategic goal for the organization. The storage strategy enabled the organization to become more agile in making business decisions via on-demand information. The server consolidation project was a key project in evolving the system infrastructure to meet the strategy (Bittman, 2004).

The research conducted was a top-down approach where each subsequent phase narrowed the feasible technologies and began to focus on the best technology-to-business fit for the organization. The avenues of the research were conducted in increasing stages of detail and involvement as possible solutions became more evident (Hacker, 1999). The stages and resources considered were as follows:

- Literature – Textbook, Trade Journals, Websites, White papers
- Seminars – Vendor and Association sponsored
- Interviews – Resellers, Vendors, Consultants, other Professionals
- Demonstrations – Vendors, Manufacturers

Upon the completion of the last research stage (demonstrations) the server staff re-evaluated their knowledge and skill-set for what would be required in order to implement and support the possible technical solutions. Key criteria in the subject knowledge stage focused on how the new technologies would compare to current staff skill-sets. The ability of the staff members to either adjust or obtain the lacking critical skills needed to support the new infrastructure would be determined and addressed accordingly.

The review of existing available solutions coupled with current subject knowledge led to a short list of considered solutions for the project. The defining consideration that promised the best Return On Investment (ROI) for the organization were virtual servers running upon blade server technology. The promising solution was a logical fit for the original infrastructure and would build on current skills sets.

Based on product research a list of hardware requirements and top blade server manufacturers was created. The hardware requirements included common server specifications, such as: CPU type/speed, number of CPUs supported, maximum RAM, system bus speed, and RAID support. In addition, further requirements were needed to address the specialized blade server technology, such as: enclosure type/size, maximum numbers of blades per enclosure, maximum number of blades per 42U rack, backplane interconnect, internal power supplies, and management software. The various hardware requirements and manufacturers were structured into a decision matrix that either qualified or disqualified the products for each requirement on a point system, See Appendix C: Product Selection Matrixes.

The entire research process was initiated by various avenues of subject literature, ranging from trade magazines to college textbooks. The initial stage proved to be the most beneficial aspect of research, because of the advantages to becoming more familiar with the overall subject at a minimal expense cost.

2.1.1 Literature

The research strategy was to initially find vendor neutral resources that gave a conceptual view of the subject. Various trade magazines and other consulting texts (refer to References) were used to gather initial information and review of available technologies, such as:

- Technology and Business Magazine
- IEEE Spectrum Magazine
- Computer World Magazine

Even though, the trade magazines, whether online or paper based, favored certain vendors, this was balanced by referencing a broad range of outlets that minimized any biases. A valuable resource to the project was found in the Gartner Group (http://www.gartner.com/Init), which was extensively used for evaluating technologies and the manufacturers providing those technologies. The strength of using Gartner consulting services was that the firm did not financially benefit from vendors. The service was marketed as having an advantage by providing unbiased information.

During the initial research phase, as certain technologies promised to be more beneficial, further focus was given to those technologies and the manufacturers providing the solutions. The next research stage was to attend manufacturer provided seminars relating to promising technologies.

2.1.2 Seminars

The Infrastructure Manager and Lead Administrator attended vendor provided seminars which discussed a range of topics dealing with enterprise computing and storage. The three seminars were hosted by two consulting firms that the organization had done business with in the past, South Seas Solutions and Technology Integrated Group (TIG).

South Seas recommended a locally based, one day seminar dealing with server consolidation solutions. The speakers from IBM featured newly released hardware products, such as the large scale p550 virtual domain server and the BladeCenter. During the lecture the speaker showcased the BladeCenter chassis, which provided fourteen server blade slots in a compact chassis enclosure. The solution was further enforced by IBM's ability to partner with a leading server virtualization company, known as VMware Inc., headquartered in Palo Alto, CA.

During the same seminar, speakers from VMware featured their flagship virtualization product, ESX, which was designed for large production environments. VMware specializes in virtual infrastructures that promise to transform an organization's data center into a single pool of resources. The abstraction that is created between physical hardware (server, storage, networking) and the installed software enable companies to leverage costs and administrative efficiencies, See Figure 3.

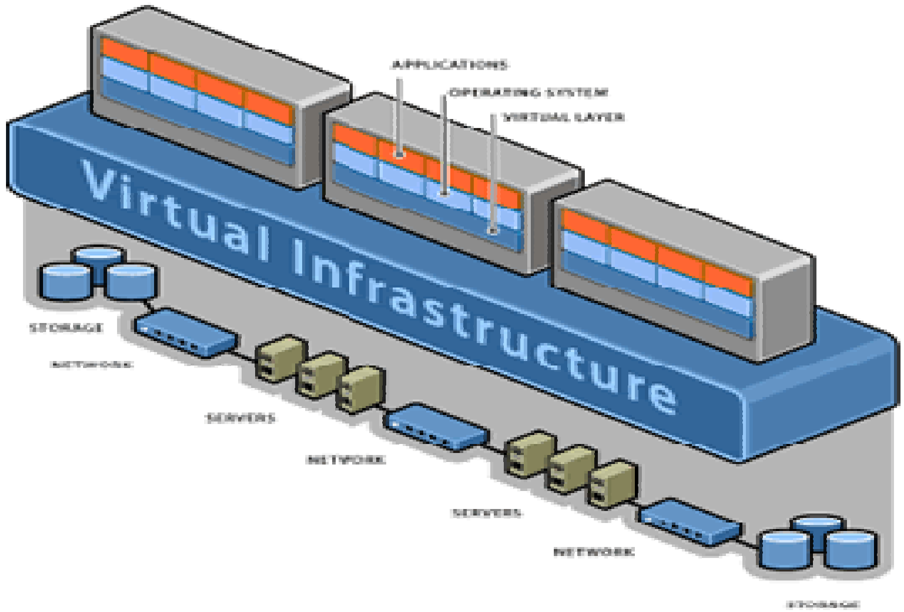

Figure 3: Virtual Infrastructure (VMware Brochure)

In a virtual infrastructure, the end user’s view of a virtual server is the exact view as would be a physical server. However, the administration view of the same server differs where instead of the server instance being directly associated on a one-to-one ratio with a hardware platform a virtual server is associated with a container. Numerous containers are able to co-exist on the same physical hardware platform. The only restricting factor to the number of containers residing on one platform would be the combined physical resources required for the virtual server instances.

The benefit of the technology solution is in the form of cost saving in hardware and labor. Both benefits are based on the fact that the system software (O/S, and applications) have been abstracted from the underlying hardware. Multiple containers residing on a single hardware platform reduces the need for server hardware. The time saving is based on the fact that the containers can be saved to disk much like a file or moved from platform to platform, whether real-time or from disk. This dramatically saves administration time. For example, once the initial base container is created it can be deployed multiple times in a matter of minutes compared to traditionally building a server, which takes hours. In addition, when an upgrade or patch needs to be applied the container can be saved to disk before hand, as a precautionary measure. If the software maintenance is unsuccessful, within minutes the original virtual server can be restored.

2.1.3 Interviews

When the textual research concluded, noted by an understanding of viable technical solutions, interviews with industry experts were conducted by following an informal request for information process. An e-mail was authored that summarized the strategy of the project and technologies being considered. The desired outcome of the request was a review of the project strategy, including the benefits, risks, and industry trends. The request was sent to a small list of familiar vendors and consultants, such as: TIG, South Seas, IBM, HP, and EMC.

An open discussion format was the primary strength of the interviews that was especially effective when a written agenda was planned. The interviews were conducted onsite in workshop settings between the vendor and the server team members. When further information gathering for a particular solution was needed, a meeting request was sent to the competing vendors for a comparison of opinions. Upon conclusion of the vendor meetings, an additional sit down session was scheduled with the Gartner Group to verify the validity of the solutions proposed by the manufacturing vendors.

The Gartner interviews consisted of conference calls between key infrastructure decision makers and analysts from the consulting service. The advantage of the service was that it would either reinforce or diminish the strategic realignment concept being developed by the server administration team.

According to the Gartner analyst, a published report (Hewitt, 2005), and a product decision matrix (See Appendix C), the top blade server manufacturers were identified as IBM and HP. The conclusion to the interviews was that both manufacturers offered near superior products that deserved further evaluation. Therefore, on-site demonstrations were conducted that involved the entire server administration team.

2.1.4 Demonstrations

On two separate occasions, the manufacturers (IBM and HP) were invited onsite to meet with the server administration team and conduct product demonstrations. Each demonstration featured the manufacture's fully functional consolidation product that the team was able to extensively evaluate.

The IBM demonstration of their blade servers and system management solution spanned three days. The demonstration consisted of delivery, racking, and installation of management server software and deployment of the Windows O/S to the blade servers. The demonstration was formatted as a hands-on "feel-n-learn" of the manufacturers' product. The IBM consulting team consisted of a sales manager, a systems technician from the third party sales vendor, and an IBM systems engineer. During the three days, the server administration team members were able to deduce various advantages and disadvantages of the IBM BladeCenter solution. The advantages that met the hardware requirements criteria specified in chapter one and Appendix C were as follows:

- IBM utilizes Director for management and monitoring, which seamlessly integrates with the BladeCenter (both products are provided by IBM).
- Third party Altiris integrates with Director for non-IBM servers/workstations/laptops deployment and updates
- Altiris can flash firmware components, as well as imaging O/S and other software.
- The BladeCenter is SNMP enabled, which is an industry monitoring standard, and can be integrated with the organizations' network monitoring system.
- InfiniBand chassis backplane is faster/more flexible than a traditional PCI bus.
- Able to cluster via InfiniBand backplane to any blade server
- Dual backplane for high availability
- Able to support mixed platforms (i.e. Xeon/Opteron/Power)
- Fail-over between blade servers through Director management software
- Standard design, future option of other vendor blades able to plug into BladeCenter chassis
- High density blade server, 14 slots per 8U chassis
- Various choices for interconnects (Ethernet, Fibre Channel, IP KVM, etc.)
- IBM blade technology is rated high by Gartner Group
- Module hardware architecture for ease of upgrades and parts replacement
- Chassis is self contained with internal power infrastructure
- Blades have 2 small form factor hard drives with RAID 1.

The following disadvantages were noted by the evaluation team:

- Possible heat issues with SCSI hard drives can lead to over heating of the entire blade chassis resulting in hardware failure.
- Organization's current standard platform is HP, which would require additional effort to shift to an IBM platform standard.
- A separate Management server, running Director and Altiris, will be required
- Currently, blades only run Xeon (32 bit), Opteron should be available the forth quarter of 2005
- The 4way CPU server blade takes up two chassis slots

On a different occasion, HP gave an on-site demonstration of their server consolidation products. The manufacturer offered a two-day demonstration where a blade chassis, half populated with high density and medium density blade servers, was delivered to the operations facility. An HP design engineer was dispatched from the technical center in Colorado Springs to conduct the demonstration. The observed advantages of the product were as follows:

- Servers already have integrated remote management (iLO), available on all Proliant servers including the blades.
- Blades have the same form factor as the 1U Proliant servers; meaning migration to blades is done by simply physically moving the two hard drives.
- Utilizing high density blades, the chassis can accommodate 16 blades

The following disadvantages were noted by the evaluating administration team:

- PCI switched backplane is less efficient for data transfer between the maximum of 16 blade servers
- High density blades do not have RAID functionality, which introduces a single point of failure for the internal storage.
- Chassis has a single backplane, which introduces a single point of failure for the internal connect between the server and chassis.
- Power infrastructure is external to the chassis, which binds the chassis to the power unit making the chassis less portable.
- Third party blades are not an option
- No integrated Floppy/CD/USB module, and reliant on network to administer, direct (local) console not provided, which is useful during a network outage.

The IBM consultants were considerably more effective in communicating the advantages of available solutions then the HP sales team, which consisted of a single technical engineer. A noticeable strategy that IBM followed was the use of strategic partnerships. In doing so, the manufacturer seemed to be more agile to customer needs and industry advances. However, the IBM and HP products were highly competitive, see Appendix C. To solidify the decision process and better identify the real world risks/benefits a visit to an unassociated company’s data center, which recently implemented blade technology, was conducted.

The reason that the company moved to blade servers was to solve facility and staff resource constraints, while still supporting the product manufacturing enterprise. The resource constraints for both organizations were similar, and also looked toward the same hardware/software technologies for a solution. The differentiating factor was that the manufacturing company had already implemented the consolidation solution. Therefore, the visiting transit server team could discuss lessons learned and identify any unforeseen risks.

The company's server and network administration staff totaled four full time employees. Even though the manufacturing company implemented blade and virtual technology to address server consolidation, a dominating reason of the project's success was based on sound processes and procedures throughout the project life-cycle. Therefore, the transit authority's server team noted that not only selecting the correct products was critical, but the methodologies and processes of designing and implementing the solution were as well.

2.2.0 Subject Knowledge

The background of the transit server administration team had a well diverse skill set, including: Windows and UNIX systems, enterprise storage, backup solutions, and client/server architecture and support. The team consisted of four administrators, which included a vacant position, and one lead position, See Appendix A. Therefore, during the initial start of the project staff resources and skill sets were made up of:

- Two Unix/Storage administrators (including the Lead)
- One general Windows administrators
- One Windows communications consultant

The knowledge of server consolidation that the team possessed was in the form of 1U rack servers with back-end data storage residing on a SAN. The lack of experience dealing with blades servers and virtual technologies was well noted. In order to reduce risk, the product vendors were asked onsite to assist in the configuration and installation of the technologies, which was purchased as a packaged installation service. Furthermore, classroom based technical training was required for all server administrators.

2.3.0 Review of Existing Solutions

The combining of similar applications or functions should be the first means of instituting server consolidation efforts. The idea of combining compatible applications onto a single hardware platform should always be the responsibility of infrastructure decision makers, which alleviates unnecessary expenses by maximizing existing hardware by consolidating software. The risk associated with application/function consolidation is that current main stream system technologies, primarily Microsoft Windows, commonly require individual hardware platforms for individual applications (i.e. a one-to-one ratio).

Historically, available consolidation solutions were only a viable choice for large scale mainframes and Windows PCs. Both solutions provided a means of running multiple operating system environments on the same physical hardware. Therefore, varying O/S types and incompatible applications could co-exist on the same hardware.

The first industry solution to address server consolidation came from the mainframe era of the 1960's when very large servers processed data from multiple applications. As the industry moved toward client/server architecture, numerous key mainframe benefits were lost. Realizing the advantages of consolidation and central management, the industry has been moving back toward the concepts of the mainframe, such as centralized storage and single enclosures.

The major industry manufacturers have reintroduced the mainframe concept to servers. However, instead of one O/S computing numerous application data, the new age mainframes (Big Boxes) use hardware partitioning that essentially virtualizes multiple operating systems and the associated applications (Anseimi, 2004). The disadvantage of the “Big Box” solution is that it is based on old technology that is inflexible because of the close dependency between software and the hardware platform, unlike software virtualization which creates a layer of abstraction between the operating system and the underlying hardware.

The Java runtime architecture made the first impression on the Intel industry by providing virtual workstations. Through advances in the technology coupled with the progress in hardware/software standards, the virtualization of enterprise class servers had become an acceptable solution in an organization’s data center infrastructure. The advantages of virtual machines are numerous; the core of the technology enabled multiple operating systems, including installed applications, to reside on one physical piece of hardware. In doing so, the number of required physical servers was reduced, along with the associated hardware maintenance agreements (Yager, 2004).

A trend in the server market that easily addresses optimization of physical space within a data center is rack mountable servers. The advantage of rack mounted servers is that space between each server is optimized. The server hardware is also more easily managed because the racked servers reside on mounting rails that allow the server to slide in and out of the cabinet rack, much like a drawer. The height of the servers is measured in units, with one unit being 1.75 inches. In order to maximize the available rack space manufacturers have developed compact 1U servers (pizza boxes) that utilize a back-end SAN. In doing so, the server can still take advantage of RAID protection via a vast amount of SAN storage without having to house the actual hard drives.

The strategy of optimizing space within the data center extended into reducing the actual size of the hardware platform (i.e. blade servers). The advantage to blade technology pertains to administration of the physical hardware, in that each blade server connection (network, power, KVM) is through the chassis backplane. Since the external cables terminate at the chassis and then are shared among the servers, required cabling is also significantly reduced. This solution is apparent when dealing with power cables. Only two power cables, for redundancy, connect to the chassis which eases cable management efforts. Any type of cable management, movement of the chassis or the rack enclosure becomes significantly easier, which equates to time savings and is cosmetically appealing.

2.4.0 Considered Solutions

The considered solutions that had potential of being a best technology-to-business fit were those that had a long-term forecast and readily fit into current skill sets, and the existing infrastructure. The desired solution was required to answer functional, logical, and physical consolidation, along with system management requirements.

The decision of the functional solution was based on the compatibility and availability of the organization's applications. To insure that applications were not conflicting, monitoring software was used to continuously track and report application performance.

Logical consolidation was used to reduce the number of required hardware platforms by placing multiple O/S on a single hardware platform. The solution complimented the physical consolidation, addressed with blade servers, by reducing facility resource overhead costs. Also, a reduction in hardware costs, such as vendor maintenance contracts and capital expenditures, was a noticeable benefit.

In addition to the above requirements, the overall server architecture needed to have the ability of local and remote central management. System management encompassed anything from entire server restores to the distribution of software updates (Enck, 2004). The chosen technologies that addressed the four overall consolidation requirements were blade servers coupled with virtualization software. The management software was integrated with the hardware architecture, with the addition of plug-in modules for software deployment and virtual server management.

2.5.0 Solution Compared to Alternatives

The advantage of the blades is that essentially they are miniaturized 1U servers, which the current staff members were accustom to supporting. The difference between a blade and 1U server was that since the blades were contained within a single chassis enclosure, the management of the servers was more streamlined and the cabling was simplified. The management efficiency came from the additional central management tools that enabled an administrator to deploy and re-provision blade servers, which was not found with traditional monitoring/management software used for stand alone servers. The blade management software enabled the creation of a blade server image and then to install that image on other blades. The image was also able to be saved for future deployment or recovery purposes (Wright, May 2005).

The advances in virtualization software had proven effective and stable in the enterprise arena. The management of the virtual servers was through a plug-in to the central management software used by the blade servers.

The product evaluations and research into the selection of manufacturers concluded with the decision to implement IBM's BladeCenter and VMware's ESX. The central management software selected was IBM's Director. The virtual management software selected was VMware's Central Manager. For software deployment Altiris's Remote Deployment was selected, since it had the ability of supporting various hardware architectures and is capable of restoring the entire spectrum of a server, including firmware, O/S, and applications.

2.6.0 Project Contribution

The contribution the project can have to the field is a proven process of reducing overhead cost for in-house data centers, while improving service. The end product of the consolidation project has the potential of empowering internal staff and to advert threats of outsourcing by adding more value compared to an outsourced solution (Arregoces, 2004).

In addition, the project offers the potential of either maintaining or reducing staff head count. The factor of staff reduction depends on the growth of the organization. If the organization is not experiencing significant growth then staff reduction is possible without affecting quality of service. However, if significant growth is occurring or is expected to occur then the maintaining of staff head count is advised.

2.7.0 Summary

The gathering of information in order to determine the best available technical solution was to evaluate all potential solutions that promised to benefit the organization. The avenues for evaluation and insight were not restricted. The most valuable resource channel proved to be the analyst firm, the Gartner Group, followed by face-to-face meetings/demonstrations by fellow organizations that recently addressed similar realignment issues.

The information gathering efforts proved beneficial in the decision making process. Since the IT department has been inadvertently moving toward consolidation by implementing 1U servers and a centralized storage unit, the solution that proved the best fit were blade servers. In addition, the blade server solution would be enhanced by virtualization, which will further reduce costs and improve service response times.

The end result of the server consolidation project essentially replaced the traditional focus from servers to more of an agile storage centric strategy.

Chapter Three: Project Methodology

3.0 Project Methodology

The applied process for the project was a waterfall methodology of the Systems Development Life Cycle (SDLC). The waterfall methodology was used to define the business problem by properly evaluating the best business-to-technology solution for the organization (Burn, 2002). The problem statement was defined, followed by information gathering and discovery. Upon finalization of the selected technology the SDLC model was closely followed during design and implementation of the new system infrastructure. Furthermore, in order to make sound decisions for the proper technological fit, the establishment of a research method was crucial.

3.1 Research Methods Used

The establishment of a research method guaranteed consistent evaluations to all potential technologies. In doing so, any initial bias, assumptions, or hidden agendas would be adverted. The research phase played a critical role in laying a foundation for the remaining project to be built upon. If the research phase was with fault then the end product would be at high risk of failure. Therefore, the research method employed the waterfall methodology and was architected into four stages consisting of (Hacker, 1999):

- Literature
- Seminars
- Interviews
- Demonstrations

The literature phase was used as a broad means of information gathering and to become familiar with the subject matter. Each subsequent research stage became more focused and involved. The utilized research method was a sub-method of the overall strategy followed by the SDLC model.

3.2 SDLC Model

The SDLC model was originally developed for enterprise application development (Burn, 2002). However, the model was adjusted for the project by replacing application references with infrastructure concepts found in the top-down network design model (Goldman, 2000). The result was effective in the successful implementation of a system architecture that addressed critical business problems.

The success of the server consolidation project depended heavily on having an organized, methodical sequence of tasks and activities that resulted in a system infrastructure that was reliable, robust, and efficient. The five phases of the SDCL were crucial in producing an end product that added value to the organization. The phases were as follows:

- Planning
- Analysis
- Design
- Implementation
- Support

System analysis enabled the project team to layout in detail the business processes, cost/benefit, and risk of all solutions to the identified business problem, thereby setting the stage for design of the problem solution. Once the problem was identified and correctly stated the only other obstacle was to identify the most feasible solution.

The first phase of the SDLC has been well underway from the initial discussion stated in this document. The phase included key documents such as defining the problems, producing a project schedule, and the confirmation of project feasibility, see Appendix A. The problem statement, defined in chapter one, can be summarized into the need for supporting the rapid expansion of the organization while maintaining IT staff head count and quality of service.

3.2.1 Analysis Phase

The analysis phase of the project was used to gather information, define system requirements, build prototypes, prioritize requirements, evaluate alternatives, and review recommendations with management. This stage began the transition from the focus of defining the business problem to the initial building of the product.

3.2.1.1 Methods and Product Research

The various aspects of server consolidation generally consisted of reducing the physical size of the data center by limiting the amount of server hardware needed and the physical size of that hardware. The areas of research focused on:

- Physical hardware partitioning for O/S consolidation
- Logical software partitioning for O/S consolidation
- Blade servers for physical hardware consolidation
- Mainframe class servers for physical hardware consolidation
- Consolidation of applications and server functions
- Remote deployment management software
- Centralized system management software
- Disaster Recovery integration
- Moving the data center to a storage centric methodology

The concept of implementing hardware (physical) partitioning between two high-capacity redundant servers was researched and considered a possible option for server consolidation. Partitioning allows each node to run its own combination of operating systems and applications for ease of hardware consolidation and software migration, called Enterprise X-Architecture technology. The technology, spear headed by IBM, combines industry-standard features with IBM mainframe-inspired capabilities to produce revolutionary advances in the I/O, memory, and performance of IBM eSeries servers. The architecture supported AIX and Linux operating systems, which was restrictive for the desired platform standards of the organization.

Blade servers were considered a viable alternative to the hardware consolidation proposed by IBM's physical partitioning. This was further enforced by the advances in software virtualization of servers, particularly VMware because of the software supporting both the Windows and Linux operating systems. Therefore, software virtualization of servers was extensively researched as a highly promising solution from the top two vendors in the industry, Microsoft and VMware (Turvey, 2004).

Enterprise class CPUs were also evaluated and forecasted to determine which had the highest potential for long term growth and support. The processors evaluated were:

- Intel Itanium
- Intel Xeon
- AMD Opteron
- IBM Power5
- HP PA-RISC

The requirements for the processors where long term market share, 32 and 64 bit capable, and support of the Windows and Linux operating systems. Based on research forecasted for the processors, the predictions for the Xeon, Opteron, and Power5 were the most favorable. The performance of the top three processors was generally close. However, the long term market share undoubtedly favored the Xeon, which is manufactured by the largest chip maker in the world, Intel.

System management software would prove to be a key component for the management of the new infrastructure. The effectiveness of the management software enabled the server staff the ability to add quality of service, while maintaining head count and the reduction of TCO. Two main pieces of software were evaluated and chosen, a central management application and a remote deployment application. The IBM Director management application would prove the best fit for the blade server solution since the software seamlessly integrated with the blade components. For the remote deployment software, Altiris was chosen because of the ability to support IBM and non-IBM platforms. Also, the partnership between IBM and Altiris provided an integrated plug-in module for the Director application.

The backup and recovery solution for the project, assigned to an accompanying project, would be a storage centric approach which utilized a disk-to-disk backup strategy. The backup method will employ two strategies, where backup to disk will be used for expedient file recovery while tape backups will be used for long term archival of the disk backup area.

Methods for disaster recovery relied on a future project that would implement an enterprise storage solution, where two geographically distance SAN units will replicate between each other, see Appendix D. In addition to requiring the recovery of critical data in the event of a disaster, the need for server restores would be needed. The means to accomplish server recovery would be either through the imaging capability of the Altiris software or virtual images. In both cases the images were saved to the SAN and in return would eventually be replicated within the storage environment. The major advantage of the server restores was that the Altiris software was capable of creating a snap shot of the server, including firmware and RAID configuration.

3.2.1.2 Research Costs and ROI

The researched costs and ROI for the chosen consolidation project promised to add value at an acceptable investment cost. The advantages for the blade server solution were that the chassis was roughly $3,000. The blade servers, ranging from $3,000 to $10,000 could be procured on an as-needed basis. Furthermore, the use of virtualization software (a cost of $5,000) had the ability of running 16 virtual servers on one physical blade depending on required hardware resources.

The ROI was measured in the reduction of tangible capital expenses, the maintaining of labor costs, and the increased quality of service. The expense of purchasing the blade chassis was a one time cost, while the virtualization software was licensed on a per physical CPU basis. Therefore, the more servers that were virtualized and placed together on the same physical platform the quicker the ROI was reached. The ROI would be totally realized in the second quarter of 2006, when the hardware and licensing maintenance contract would be reviewed and adjusted.

The Gartner Group recommended the most efficient use of the new architecture through the virtualization of underutilized servers. Therefore, the metrics (CPU, Memory, disk usage) of the organization's servers were recorded and graphed using an existing network monitoring system, See Appendix C: Server Performance Comparisons. Servers that were routinely underutilized were batch systems and specialized back-office applications, such as:

- The data warehouse server
- The anti-spyware server for desktops
- The anti-virus server for desktops and servers
- Windows patch management server

These servers were the first candidates for virtualization because of the short downtime allowed without any disruption to end user services. By following this strategy, the administration team would be able to become more familiar and confident in the virtualization software without impacting quality of service to the end users.

3.2.1.3 Identify Current Systems

The previous servers residing in the data center varied from a legacy Dec Alpha server running VMS to third generation HP Proliants running Windows 2003. A small handful of desktops and workstations improvised as lightweight servers.

The systems were spread throughout the data center. The majority of servers resided in six standard 42u rack cabinets that contain 40 of the 64 servers. Four of the racks housed Windows/Intel based servers that were managed through a Belkin KVM console switch box. The two remaining racks contained the UNIX based servers and an enterprise tape library. These servers were managed through a next generation IP KVM appliance. All other servers were tower enclosures and scattered throughout the room, whether on the floor or on a shelf, see Appendix C.

Power running to all servers was through two data center circuit distribution panels. Instead of rack certified Power Distribution Units (PDU) used within the server racks, common office grade power strips were used. The redundant power supplies in each server were plugged into the same power strip creating a single point of failure.

3.2.1.4 Server Consolidation Candidates

The entire server infrastructure for the organization, including new and ready to be retired server hardware, consisted of 64 total hardware platforms with server roles, see Appendix B. Of the 64 servers 58 of them were Intel based running either Windows

2000 or 2003. Furthermore, of those 58 Intel servers 15 of them could be retired by either consolidating applications or retiring the function of the server, See Appendix C: Retired Server Hardware.

The remaining Intel based servers that had special purposes would not be migrated to the blade infrastructure. These servers were restricted because of incompatibility or the need for hardware isolation. Servers within the firewall service network, known as the De-Militarized Zone (DMZ), were required to be physically separate from the internal corporate network for security purposes. The requirement was not possible when employing blade technology because of the shared backplane and switching modules. Also, the legacy servers were not selected for migration because the required O/S and hardware (Tru64 UNIX/Alpha and VMS/Alpha) were not supported within the blade infrastructure. The inability to migrate the legacy servers was acceptable because near future projects would retire the seven servers in question.

Therefore, out of the total 64 servers in the data center 31 servers had the potential of being migrated to a blade server. Of the 31 servers 25 of them would be considered for virtualization. Servers not initially considered for virtualization had key roles in servicing the organization, hence would not be initially considered for virtualization in this project in order to advert any undue risk. The servers consisted of back-end database servers and turn-key systems jointly supported by the vendor.

3.2.1.5 Develop Proposal for Upper Management

The development of a business proposal for upper management consisted of a problem statement, hardware/software vendor quotes, and available budget. An important aspect of the proposal was providing a project plan that included a timeline and task dependencies.

3.2.1.6 Develop Project Plan

The development of the project plan was created within Microsoft Project. The brainstorming of tasks was noted then organized into a Work Breakdown Schedule (WBS). The WBS went through several revisions until a viable plan was agreed upon by the server team. Once the WBS was finalized a timeline was applied relative to the tasks dependencies, see Appendix A: Project Schedule.

A known project risk that was noted and tentatively planned for was the inability for the IT department to control the actual procurement process. The procurement department for the entire organization had a written policy that all purchase requests, under $250,000, would be processed within six weeks. The reason for the six week delay was directly related to the fact that the organization was mandated to justify and make purchase requests available for public bid. Therefore, within the project schedule, a buffer of 2 additional weeks was placed between the procurement tasks and product implementation.

In knowing the delays of the purchasing department, RFQs were pre-drafted and submitted early to the finance department. The early submittal included hardware/software requests as soon as the requirements were defined. Also requests for training were submitted early in the project when the final products were selected, see Appendix C. However, due to the mass amount of purchase requests (PR) submitted from throughout the organization, the procurement department became quickly inundated, which led to the blade server PR not being processed for 5 months. The implementation phase of the project was accumulatively pushed back for a total of two months off schedule due to the procurement constraints.

3.2.1.7 Develop Training Requirements

The training requirements were classroom based with a mixture of textbook and hands-on lab exercises. Other aspects of training entailed verbal and written knowledge transfer between the vendor engineers and the server team for the duration of the implementation.

3.2.1.8 Develop Quality Assurance Requirements

The dominating requirement was the successful physical to virtual migration of a server with the end product having the same or better performance and reliability as before. Other servers that were migrated solely to a dedicated blade were expected to have an increased performance factor, none the less the same requirements that applied to the virtual migrations applied to the physical migrations.

Reliable monitoring and alerting of a system, including physical and virtual environments through the Director software was another key requirement for the project. In addition, the use of the VMware Central Manager for the successful movement of virtual servers from one host to another with only a delay of performance measured in seconds was a requirement measure.

The migration of the original servers to the blade infrastructure with minimal to zero impact on the user community was a continuing theme that was regularly enforced by the lead administrator.

3.2.2 Design Phase

The design phase of the project took the chosen technologies and products from the analysis phase to build a comprehensive system infrastructure. The infrastructure included the blade chassis rack design which consisted of power, network, SAN, KVM, and cooling. Also, the design required the configuration of a separate management server that physically administrated the blade platform, and virtual infrastructure. A comprehensive solution for SAN storage requirements was also addressed, along with the storage of server images for future redeployment and disaster recovery purposes.

3.2.2.1 Design Combined Technologies

Initially, the blade chassis was populated with six blade servers. The five IBM HS20s (Dual 3.6GHZ Xeon with 4Gigs of RAM) addressed high demand servers. One HS40 (Quad 3.6 GHZ Xeon with 8Gigs of RAM) was solely used for the virtualization of lightweight servers. The reason for procuring the more powerful HS40 was that the more resources within the blade gave greater flexibility of allocating resources to a larger pool of virtual servers.

The system design specified that three of the five HS20s would run the VMware environment. However, only one server instance per blade would run on each of these three blades. The reasoning behind this strategy was that as the server instance was conditioned for efficiency, more virtual instances would be placed on the platform without degrading performance. The HS20s contained less virtual servers, however, the role of those servers had high visibility to the user community and a greater impact in the event of a service outage.

The remaining two HS20s only ran in the physical environment. The two blades were utilized for the up most demanding applications which were at the core of the organization's ability to properly service the public. The two applications were Oracle applications and EISI's ArchGIS framework.

3.2.2.2 Design Procedures

The design took a methodical approach where initial documentation was created that would include a WBS, network diagrams of affected systems, and a structural diagram of the new architecture. Also, each system that was selected for migration to either a blade or virtual server would have fully updated hardware and software documentation, which included historical performance reports.

3.2.2.3 Design Training Plan

The blade server architecture and central management server were at the core of the new infrastructure. The platform migrations were conducted while providing continual service of the blade chassis. Therefore, training was included on how to best integrate and perform maintenance on any component, while the chassis was still operational.

Aspects of the required training for the server team dealt with the various methods of how to install, configure, manage, and integrate message alerts from other monitoring software using the IBM Director software.

Remote management of the chassis and blade servers through the KVM console modules was crucial in providing quality of service. The server team had hands-on labs demonstrating how remote management and recovery could be conducted by utilizing the IP based KVM modules.

The Altiris Remote Deployment software was fundamental for software updates and the creation of server images that included the firmware and RAID configurations of the server hardware. Furthermore, the created server images were used to propagate the remaining blade servers during training lab exercises. The installation and configuration of the blades were demonstrated by utilizing the Altiris software. The deployment of software updates and upgrades followed the same exercise techniques.

The VMware architecture was a key component of the new infrastructure that required extensive training. The training format was classroom based with supplemental labs. The agenda included how to best create the virtual environment, including the proper allocation of physical resources to the virtual server instances.

Once the intuitive understanding of the architecture was established, the instructor led the class in the process of migrating physical servers to the virtual environment. In addition the instructor demonstrated how to move the virtual instances from one virtual server host to another without service interruption.

3.2.2.4 Design Quality Assurance Plan

The quality assurance plan was centered on the documented server list and historical performance reports. Each application and server resource on the new platform was monitored and compared to historical data of the old platform. If performance was equal or greater, then the migration for that server would be deemed successful. If performance was considerably reduced than the back-out plan would be to migrate to the original platform, since it was still intact.

3.2.3 Testing Phase

The testing phase of the project was conducted in three stages of success, as follows:

- Server was able to fully boot and interact with the network
- Systems dependent on the server were operational
- Performance and availability were either the same or greater when compared to the original platform

Based on the results of the three testing stages, the decision to either continue or revert to the original platform was decided by the lead system administrator. If the server was reverted then a re-evaluation and possible reconstruction of the prototype was done to determine the problem and solution. Where upon, the prototype’s hardware and software configurations were re-documented in preparation for a second attempt at implementation.

The key to properly building the server prototypes and the proceeding production servers was to have the server staff properly trained in the new technology and products.

3.2.3.1 Establish and Execute Training Plan

The designed training plan, based on the requirements for filling the server team skills gap, was to be scheduled and attended by each team member. Three training courses (BladeCenter/Director, Altiris, and VMware) were attended by the four team members on a staggered basis of two groups.

3.2.3.2 Build Prototype

After vendor services had racked the blade chassis and assisted in the setup of the Director/Altris management server, a blade server prototype was built by the server team.

The initial prototypes were built for less critical and less complex servers that could tolerate a short term outage. The idea behind the strategy was that as the server team became proficient with the new architecture and the migration process, the better prepared they would be for the migration of more critical servers.

3.2.3.3 Document Hardware and Software

Once the server prototype had been properly built and passed the three stages of testing, detailed hardware and software documents were created.

In order to prevent the server team from bypassing the essential process of documentation, the process occurred after each successful prototype build instead of at the end of the final migration.

3.2.3.4 Establish Quality Assurance Plan

The quality assurance plan was established by assigning the responsibility of comparing current and historical performance matrixes between the new and old platforms to an individual not involved with the build of the prototypes. In essence, the responsible party took on the role of a technical auditor, who made recommendations to the lead system administrator on whether to continue with the migration or more design work was needed.

3.2.4 Implementation Phase

The implementation phase of the project was conducted in a waterfall methodology for each selected server. The dependencies of the server were noted by referencing the system diagrams gathered during the procedures section of the design phase, see Appendix B.

3.2.4.1 Select and Prioritize Server List

All servers residing in the data center were listed along with basic information such as:

- Hostname
- Purpose
- Hardware Model
- CPU (quantity/speed)
- Amount of RAM

- Storage type and amount.
- Operating System
- Asset tags and serial number
- IP address

The strategy for selecting which servers would be moved to the blade servers, and of those, would be converted into a virtual machine was by criticality. Highly critical enterprise servers, such as Exchange, would either stay on existing hardware or would migrate solely to a HS20 blade. Other less sensitive servers that could tolerate short term service outages were converted to virtual machines that would reside on the HS40 blade. These servers could include such services as file/printing, antivirus, intranet, and small project servers, See Appendix C: Migration Candidates.

3.2.4.2 Begin Migration of Servers

Depending on the criticality of the migrating server, the move happened during working hours or during the weekend when the Administration department was off. The server was either built on a blade or converted to a virtual server, but in both scenarios the original server was left intact. If for some reason, the migration failed the original server could be brought back online as a final back-out plan.

A key goal of the consolidation project, as stated in the goals and requirements section of chapter 1, was to migrate at least twelve servers to the new blade infrastructure. This meant that either seven of the servers were virtualized or the function of servers would be combined within one operating system. The remaining five servers were considered critical to the functionality of the organization.

The time span for the implementation was expected to take no longer than four weeks, which included a buffer of a week for unexpected delays.

3.2.5 Maintenance Phase

The project maintenance phase began when the successful migration of the first server was made to the new infrastructure.   During the remaining migrations each migrated server required the day-to-day attention normally given to the system. Therefore, a team member was assigned to solely monitor and spear head the daily support of the migrated systems.

3.2.5.1 Document Licenses and Serial/Part Numbers

Each server that was migrated had all operating system, application, and hardware licenses documented and stored in a physical folder marked with that server's hostname for auditing purposes. In additional, an electronic version of the folder was housed on a secured shared drive along with all serial/part numbers. A full server specifications documents accompanied each server that detailed all system resources and configurations.

3.2.5.2 Documented Methods of Procedure

Each server had a specific purpose that required specific hardware or software. In order to properly maintain a high service level for each system all procedures (maintenance, upgrades, troubleshooting) were documented.

The documentation followed a format of informing interested individuals by following specified strategies. The first strategy was to establish a detailed understanding of the procedures, a general description of the system, and a network systems diagram. The maintenance and upgrade procedures consisted of step-by-step instructional tutorials that included narrative explanations and followed detailed screenshots where necessary.

3.2.5.3 Lessons Learned Document

The lessons learned document was a type of summary that highlighted the strengths and weaknesses of the project. Since hind sight is 20/20, recommendations were noted on how the project could have been improved or made more efficient. The recommendations included managerial, technical, budgetary, and culture constraints.

3.3 Review of the Deliverables from Each Phase

The deliverables from each phase were critical in executing the proceeding phases and review of the current project success. Each deliverable was used not only as a guideline, but to have senior management's review for approval and continuing involvement.

Setting milestones for each phase of the project was a means implementing an auditing and approval process, which forced the server team into producing a quality product throughout the project.

3.4 Review of the Milestones from Each Phase

The milestones for each phase were simple in nature. A standard form was created that showed the progress of the project, concerns, risks, and failures. Each category received a rating from one to five and a color. The three colors where green (on track), yellow (at risk), or red (near failure). Between the numeric rating and the color scheme management quickly knew the status of the project at any given time.

3.5 Project Methodology Summary

The methodologies used throughout the project paralleled all phase of the SDLC. For the creation of the project, a top-down design model was applied for each stage of the SDLC, in the form a waterfall methodology. The project management aspect was two fold where the waterfall methodology was also applied. The first strategy of the project management portion was to be able to adjust the planning and scheduling of the project due to unknown or unanticipated circumstances. Therefore, the idea of discovery, management, and re-evaluation was constantly iterated throughout to insure that the project was not at risk.

Secondly, to further reduce risk and keep upper management involved milestones were created at the end of every phase. Each milestone required the re-evaluation by the lead systems administrator, and then a summary report was submitted to upper management. If upper management approved of the results stated in the report then the phase was deemed successful and the next phase was initiated. However, if the report was unacceptable, then the concerns were documented for review and correction.

Chapter Four: Project History

The server consolidation project was initiated because of upper management's strategy to conserve resources in the form of hardware and labor costs over a span of several years. The legacy technology had been able to service the organization, but only at a slowly diminishing grade of quality. Throughout the history of the data center the organization had not experienced any dramatic changes in service demand, therefore the infrastructure was in a maintenance mode for the majority of the time. In addition, there was minimal concern or need to utilize current technologies.

4.1 Project Basis

The approval of the metro wide Light Rail expansion and a new ERP were two large projects that would dramatically change the way the organization conducted day-to-day business. Therefore, the antiquated system infrastructure within the data center would have to be addressed.

The basis for the server consolidation project was to realign the function of the data center to current and future needs of the organization by reducing the required facility resources and increasing service agility. The organization would also benefit from the project by having the ability to maintain staff head count, while accommodating added system responsibilities.

The two main goals of the project were to lower TCO and add quality of service. These two competing goals were accomplished by introducing a server consolidation solution coupled with centralized system management software.

4.2 Project Management Methodology

Project management followed the waterfall methodology, especially during the design and implementation phases of the project. The reasoning behind the decision to utilize the methodology was that each phase output logically flowed directly into the next phase of the project (McGary, 2003).

In addition, the methodology was consistently followed within each project phase, such as the research stage of the analysis phase. The initial research stage started with a broad scope with each subsequent stage having a narrowing scope. Each stage input was dependent on the output from the previous stage.

The most time consuming and critical aspect of the project was the management of procurement. Procurement planning was controlled by the IT department and took a matter of one or two weeks to review and recommend the purchase of specified hardware, software, and training. Unfortunately, the remaining aspects (solicitation, source selection, contract administration, and closeout) were the responsibility of the purchasing department. With the rate of organizational growth, the purchasing department was quickly overloaded with requests and the subsequent bidding process.

The inability of controlling the critical aspect of the project continually put the project at high risk for missing deadlines. The implementation phase of the project was accumulatively pushed back for a total of two months off schedule due to procurement constraints.

4.3 Success of the Project

The success of the project was determined by the project goal of twelve servers being migrated to the blade chassis containing six blade servers. Upper management was pleased with the average ratio of two-to-one, however a higher ratio would be more attainable as the server team became more confident and affluent with the virtual infrastructure. The virtualization of the servers directly affected the reduction in TCO, by discontinuing hardware maintenance agreements for original hardware platforms. In addition, server performance and stability were only positively effected because of the ability in the VMware manager to accurately size and allocate needed hardware resources to each virtual container.

4.4 Change Management

The management processes required to properly commit the right amount of resources for success was to fully define and manage the project scope. The initiation, planning, definition, and verification of the project was tightly controlled through three key decision makers that consisted of the Program Office Manager, Infrastructure Manager, and the Lead System Administrator. Therefore, the initial change management processes were easily managed and well documented. However, the integration of change control required more time, especially from the Lead System Administrator who received the majority of change requests from the server team. In order to properly track and approve the requests a centralized collaboration method was implemented.

The centralized collaboration solution was through an in-house developed, web enabled, program that tracked each change request via a back-end database. The decision process for each request was automatically e-mailed to certain decision makers for review. Each request was required to contain the date/time for the change, system/server being affected, the person(s) responsible, and a description. The response from the decision makers could be either granted, denied, or need for further information and review. The latter response would usually result in a sit down meeting between the server team and other requested IT staff members.

4.5 Project Closure

The closure of the project was determined when the project goal of having twelve servers migrated to the new infrastructure was met. An off-site closure meeting was scheduled where lunch was served. Acknowledgements were made to each team member for their efforts and dedication to the project. Further, a brief statement was made by the Senior IT Manager that summarized the business problem and how the server consolidation project was a successful solution to the problem.

4.7 Findings and Analysis Results

The analyses of the results were positive for the consolidation of the servers to the blade and virtual platforms. The features of the VMware manager were used to better allocate physical hardware resources to each of the virtual servers. For example, the CPU utilization for the AutoCAD server (marked as underutilized) was adjusted to better fit the needs of the application. The noticeable difference was that prior to the migration the CPU usages averaged three percent, with only one spike above five percent.

After the migration to a virtual server, the CPU utilization was better allocated, with average usage near fifteen percent, See Appendix C: Performance Comparisons. The change occurred because the VMware manager was used to reallocate the unused processor time. The benefit this had for the organization was that the AutoCAD application resided on a standalone server, which required a hardware maintenance agreement that was no longer needed and the unused resources (CPU, memory) were better allocated to other servers.

The overall design evaluation of the data center revealed the need for extensive re-architecture, See Appendix C: Data Center Floor Plan. The data center's UPS was manufactured in 1996 and refurbished prior to installation in 2000. The unit was well over the five year life span for the onboard circuitry, namely the capacitors. Another, issue was the age of the two Liebert HVAC systems that were installed in 1990. The manufacturer's specification stated an 8 year life-span for the systems. To a lesser extent, the data center floor tiles were carpeted, instead of non-static vinyl, which periodically cause static discharge.

A positive finding from the project results was that by preparing for the arrival of the blade chassis, nine server hardware platforms were retired and two were outsourced, See Appendix C: Retired Server Hardware. By retiring the legacy servers, the organization was able to reduce the annual hardware maintenance agreement from $180,000 to $147,000 for an annual savings of $33,000. The anticipated savings from old Intel based hardware that the selected servers were migrated from was estimated at $45,000. The actual saving would not be known until the annual hardware maintenance agreement was reviewed and a price quote was received by the vendor of the awarded support contract, which would be due in July of 2006.

4.9 Project Summary

The server consolidation project was initiated by a need to lower TCO and increase quality of service in response to two very large projects in the near future. The data center was in a state of disarray with a patchwork of end-of-life hardware, workstations running as servers, power/network/SAN cables all intertwined under a raised floor, and the absence of any type of central management software.

The project was able to bring the system infrastructure up-to-date by introducing a new architecture that followed an organized plan and design methodology. By doing so, processes and procedures could be standardized and managed through central management software.

A concern for the new infrastructure was that the heat and power requirements of the blade servers would exceed the capabilities of the UPS and the HVAC systems. On the contrary, since twelve servers were migrated to the new platform and nine other legacy servers were retired, the net effect of the facility resources was reduced. The resource reduction was primarily due to the retired hardware that required 208V power, and housed an excessive amount of low storage capacity hard drives that combined to produce an exceptional amount of heat.

The overall project was deemed a success by upper management and paved the way for future projects, ideas such as wide area clustering of the data centers.

Chapter Five: Lessons Learned

The lessons learned are viewed through the author's perspective looking back on the entire server consolidation project. The chapter will focus on what was intended and the successes and difficulty while working towards the goals of the project.

5.1 Learning from the Project Experience

The experiences of the project can be categorized into two parts: technical and the human factor. Since, the infrastructure platform was a Commercial-Off-The-Shelf (COTS) solution there was extensive support available from the vendor and other sources for proper component selection and implementation. However, the project management portion that dealt with the human factor was the most time consuming and sensitive portion of the project. Furthermore, as the project progressed and further interest was given to the project, the more individuals wanted to impose their own strategies to the solution. This had a negative affect on the project scope, the project schedule's critical path, and in some cases, deviation from the primary goals.

5.2 What Would Have Done Differently

Looking back on the entire process for the server consolidation project what should have been done differently was research for an overall infrastructure (network, system, telecom) and strategic staffing skills plan before initiating the server consolidation project. Based on the research, an Infrastructure Maturity Model (IMM) for the organization should have been created as a long term strategic goal for the IT department. In doing so, the server consolidation project would be a deliverable, which other projects would be built upon, including goals beyond the server infrastructure such as application and database development (Bittman, 2004). During the consolidation project many flaws in the infrastructure where discovered that were beyond the scope of the project. If an IMM strategic plan was developed many of the unforeseen flaws would have been noted and properly dealt with in an overall methodical approach that built upon subsequent phases. Instead, as the flaws were discovered additional projects were created, which led to conflicting requirements and constraints on staffing and budgetary resources.

The research of the blade products should have been more in depth pertaining to the evaluation of the technology. An advantage that was noted for the IBM BladeCenter was a module hardware design, where individual components could be replaced as newer or failed hardware occurred. The module strategy did not always hold true, for example late in the project it was discovered that dual-core processors would be available in the BladeCenter chassis.   However, IBM required the replacement of the entire chassis and not just the upgrade of the chassis backplane. Therefore, provisions should have been made within the hardware warranty pertaining to any associated costs or risks in the required placement of components. This is due to the evolution of the product beyond any desired upgrades requested by the organization. The manufacturer would be required to cover costs and inform the organization, in advance, of any strategic changes for the procured products.

Other factors that would have been done differently regarded the fact that the Human Resources department failed to fill a key systems administration position during the first half of the project. Upon the final hiring of the individual, the resource constraints were not fully met until the project was well into implementation and the beginning of the support phases. The new administrator had to overcome not only the dealings of the project, but the day-to-day responsibilities of the server team.

Furthermore, in order to ease staff management difficulties a formal presentation during the planning phase should have taken place with the entire server team discussing the business needs and solutions. Also, a clear understanding of the roles and responsibilities should have been discussed during the meeting instead of a one-on-one basis between the lead and other administrators. If done, a vision would have been conveyed to the team, giving each individual more ownership and commitment in the project.

5.3 DID the Project Meet Initial Expectations

The project expectations were to lower overhead costs associated with in-house data centers by reducing the required facility resources and increasing service quality through server consolidation. The additional benefit of maintaining staff head count, while accommodating added system responsibilities, would be feasible with centralized management software.

The project did meet the initial and long term expectations by promising to maintain head count while lowering TCO. Lowering TCO was accomplished in various aspects of the project which accumulated into a cost savings for the organization. A total of eighteen hardware platforms were retired by the use of the virtual infrastructure.

Selected legacy servers made up twelve of the retired platforms for a cost saving in hardware maintenance support of $33,000 annually.

5.4 Next Evolution Stage of the Project

The next evolution of the project would be to introduce an enterprise wide resilient network solution via wide area SAN replication and system clustering, see Appendix D. This would enable both of the organization's data centers to fail over to the other in real time.

5.5 Conclusions

The server consolidation project became a spring board to revitalize the vigor of the data center and agility to streamline the needs of the organization. The momentum regained by the success of the project was crucial in initiating future infrastructure projects.

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APPENDIX: A

Project Plan

- Project Charter
- Project Scope
- Project Schedule
- Capital Budget
- Roles and Responsibilities

Project Charter

The initial proposal of the server consolidation project has numerous benefits that address the short comings of the current system infrastructure. While the short and long term needs of the organization can be addressed in various ways, such as mainframe technology or outsourcing, the proposed solution is highly recommended.

The consolidation project will streamline system administration functions to the requirements of the business. The advantage of the solution is based on providing agility within the organization's data center while not inflating costs beyond the financial benefits to the project.

In order to properly plan, design, and implement the solution, the support of key department heads is crucial. The department support includes:

- Information Technology
- Administration
- Purchasing
- Legal

In addition to the direct support of the above departments, it is equally important to have support from other departments who depend on the effected systems, such as:

- Security (Access Control)
- Finance (Union Payroll)
- Planning and Scheduling (GIS and Trip Planner)
- Facility Maintenance (Task Management)
- Treasury (Fare box Management)

Therefore, the core project planners (Program Manager, Infrastructure Manager, and Lead System Administrator) authored an extensive business due diligence report. The report details the overall strategic vision of the IT department and the projects that will meet the vision goals.

The effort behind the report is to proactively answer questions regarding the various IT projects that may other wise seem unrelated. The desired result is to better align similar efforts between the various departments.

The report was submitted to the four key department heads that directly approve and fund IT projects. The formal approval and support of the report would be sought and used as a basis for project sponsorship of the server consolidation project. Other interested parties would be provided the report upon request.

Project Scope

History

In recent years advances in server architecture has enabled corporations the ability of reducing the size of data centers while gaining added performance and services. The ability to physically and logically consolidate servers into fewer and smaller hardware platforms can reduce data center overhead costs.

Technical Solution

In order to take advantage of the recent advances in server architecture, a server consolidation project will be proposed that utilizes blade technology, coupled with virtualization of servers. In doing so, the data center foot print can be dramatically reduced. In addition, server virtualization will reduce the number of required hardware platforms, which will lead to greater efficiencies and lower cost of ownership.

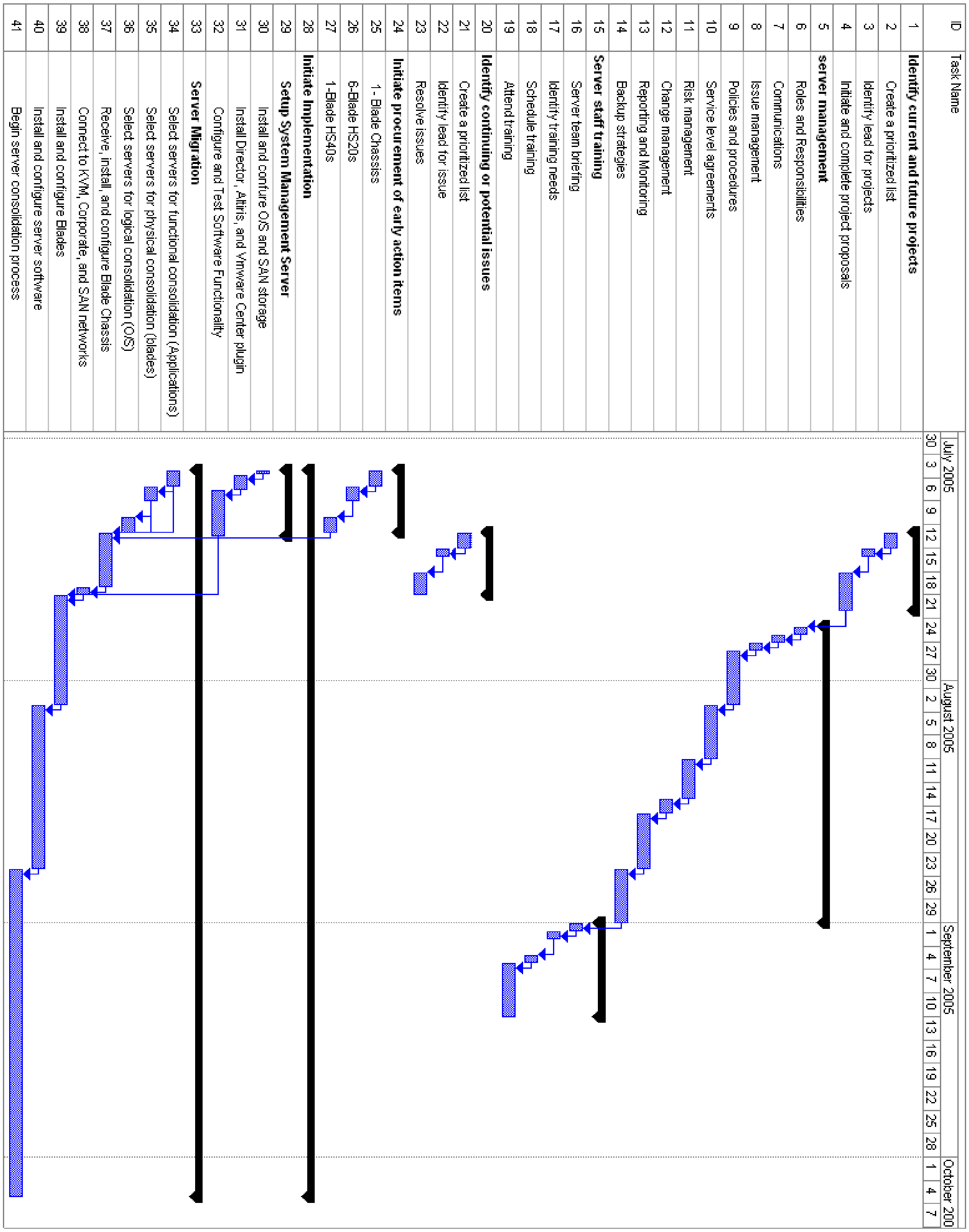
Project Scope

A means of reducing overhead costs associated with in-house data centers is to reduce the required facility resources through server consolidation. The reduction in the data center foot print will require less real estate, lighting, fire suppression infrastructure, and HVAC services. In addition, since the numerous stand alone servers are now consolidated into one or two blade server enclosures, system administration becomes more efficient.

The project will span four months from project charter to product implementation. The forecasted capital budget for the project is estimated at $100,000. This includes server hardware, software, and training. The ROI is estimated at 18 months with significant saving from retirement of legacy hardware, reduced facility costs, and maintaining of staff head count.

The intangible benefits of the project will be in the form of a more agile data center that is able to respond more efficiently to the organization's requirements.

Project Schedule



Capital Budget

While the expenditures are planned to occur over the next eighteen months, the total capital cost of a secondary data center, primary data center upgrades, disaster recovery, and an ERP includes:

ITEM	UNITS	UNIT PRICE	TOTAL COST
Database Servers	12	$ 58,000	$ 696,000
Base Blade Chassis	4	17,000	68,000
Application Servers	19	17,000	323,000
Routers	2	49,500	99,000
Project Office SAN unit	1	430,000	430,000
Oracle DataGuard	2	120,000	240,000
Data Center Upgrade	1	150,000	150,000
Tape Drives	2	5,000	10,000
Project Office Firewall	1	20,000	20,000
Disk Backup Solution	1	75,000	75,000
Miscellaneous		~5%	100,000
TOTAL			$2,211,000

The available fiscal year of 2005 budget for hardware/software includes:

Computer/Network Hardware	$ 1,280,627
Software	456,744
Project Office	325,000
Total	$ 2,062,371

The available budget for the fiscal year, 2005, is sufficient enough to accommodate the initial build of the secondary data center at the project office and execute the server consolidation project. Other less critical project objectives can be put off until the fiscal 2006 budget is made available.

Roles and Responsibilities
Server Administration Team

Lead Network System Administrator
- Infrastructure Planning and Project Management
- Strategic Coordination.
- Service Level Agreement Compliance.
- Oversight of system implementation and maintenance.
- Data Center management.

Enterprise System Technical Expert
- Support of legacy and Oracle database, and scheduling servers.
- District wide backup and recovery of all servers and workstations.
- Enterprise E-mail recovery system.
- Enterprise storage management: including direct attached and SAN unit.
- Support of core applications working closely with programmers and DBAs.
- Unix/Linux O/S Administration and assisting in the support of windows systems.

Network Computer Support Analyst
- Support of payroll system.
- Support of Automatic Passenger Counting system.
- Support of GIS infrastructure.
- Support of real-time information website to public.
- Support of Pass Monitoring System.
- Support of Route scheduling system.
- Support of public comment system.
- Support of Web Portal infrastructure.

Network Computer Support Analyst (Vacant)
- Support of E-mail spam filtering.
- Support of Anti-virus updates and filtering.
- Support of windows updates and patches.
- Support of document controls system.
- Support of Project Management system.
- Support of AutoCAD (Engineering Design).

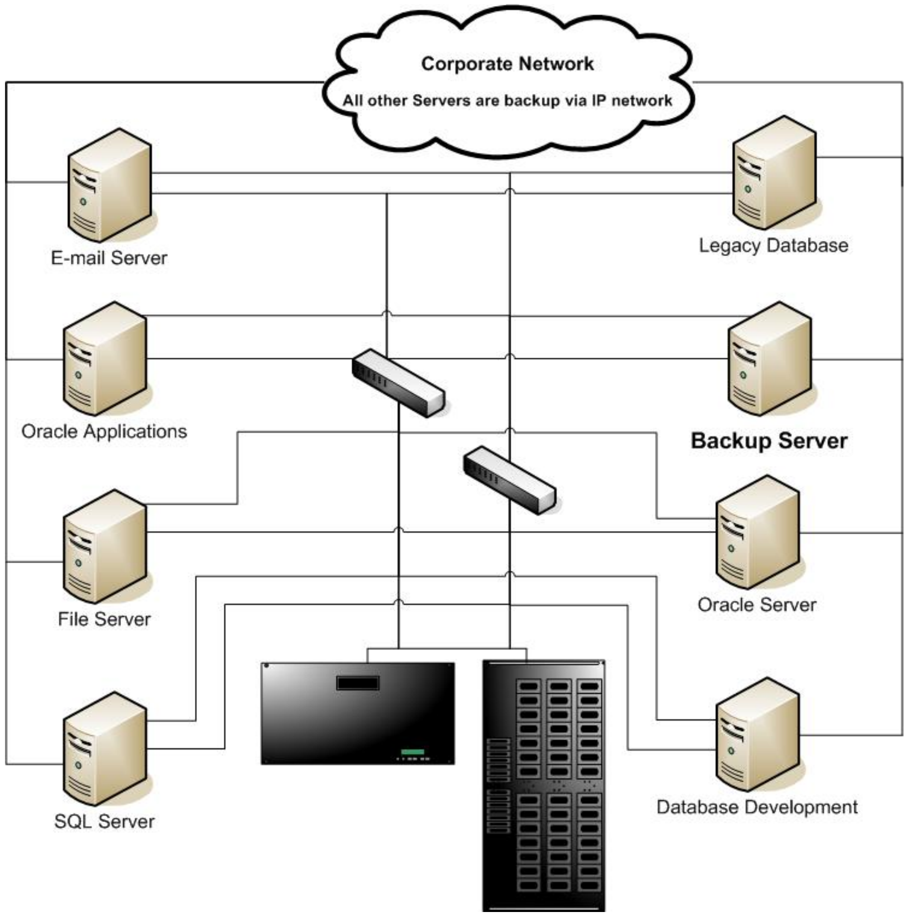
Contracted Windows Systems Administrator
- Implementation and maintenance of Exchange e-mail system.
- External web e-mail system.
- Support of Windows user accounts, group/security policies (Active Directory).
- Support of Windows DHCP and DNS services.
- Support backend Windows SQL database for specialized systems.

APPENDIX: B

Network System Diagrams

- Backup and Recovery System
- Central Data Storage System
- Central Faxing System
- Database Integration System
- Facility Access Control System
- Facility Task Management System
- GIS System
- Messaging and Collaboration System
- Payroll System
- Remote Desktop Deployment System
- Spyware and Antivirus System
- Trip Planner System
- Web Policy Enforcement System
- Windows Domain System

Backup and Recovery System

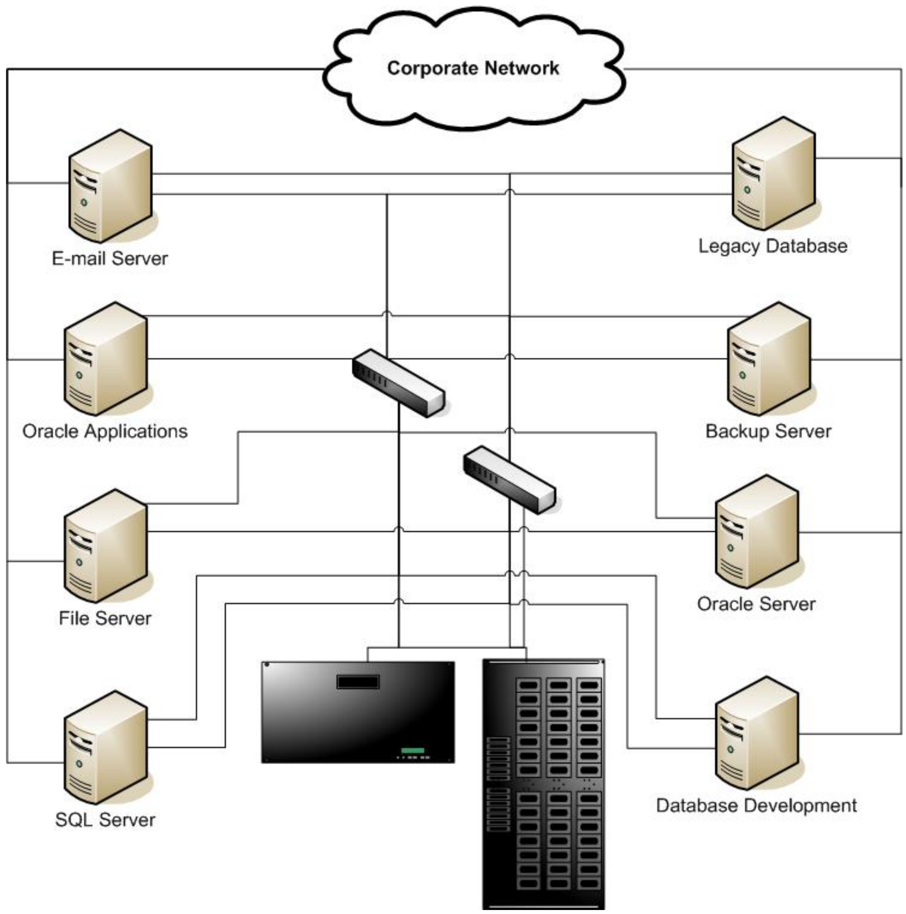


The backup Server is directly connected to the Fibre Channel SAN environment along with seven other enterprise servers. The other two devices on the SAN are a tape library, with two tape drives, and a multi-terabyte disk array. All the devices are interconnected through two redundant Fibre switches.

When a server is instructed by the backup server, that server will backup its files to what appear to be two locally attached tape drives. Afterward, that server sends an index list of files that were backed up.

If a server, not connected to the SAN, is instructed to backup, it does so over the corporate network directly to the backup server. The backup server then sends the files to tape and creates the index of files.

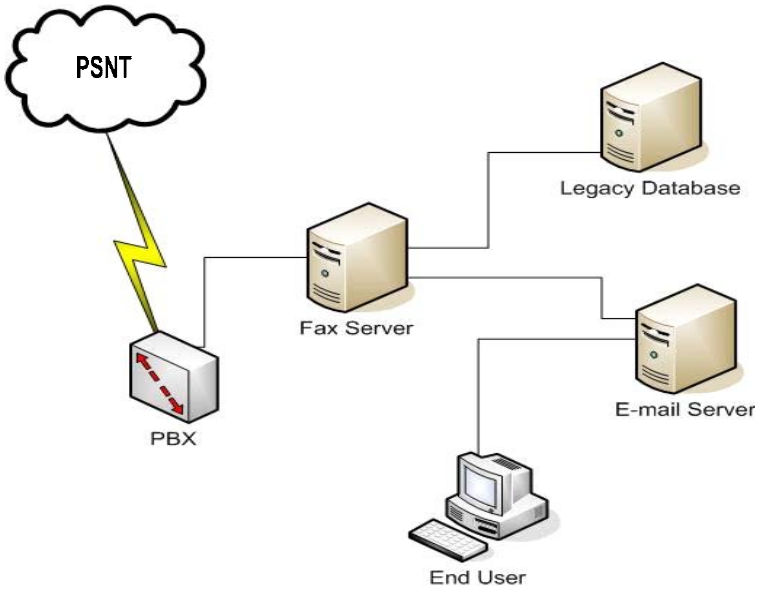
Central Data Storage System



The Storage Area Network (SAN) is a Fibre Channel Protocol based network. All devices are interconnected using multi-mode fiber cable to two redundant Fibre switches. The disk array houses Fibre Channel hard drives and is capable of storing up to thirty-six terabyte of data. The tape library has two tape drives and is capable of storing up to fifty-two high-density 350Gig tapes.

Data that is passed over the SAN infrastructure can be transferred up to two gigabytes per second. End-users that need to access the data do so through the corporate network to the respectful server.

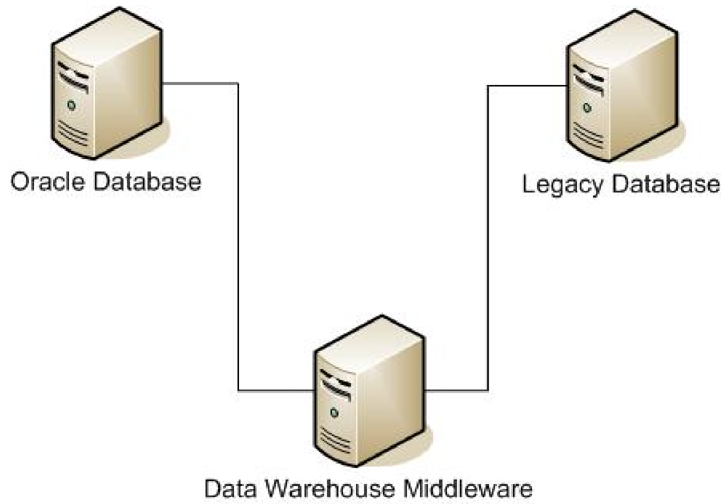
Central Faxing System



The central faxing system consists of one standalone server with a specialized T-1 modem card. The faxes are formatted then sent to the corporate PBX where they are passed to the public telephone network.

Outgoing faxes can be sent from either e-mail or database server. Incoming faxes are configured, through the PBX IDEs, to be routed to specified e-mail accounts.

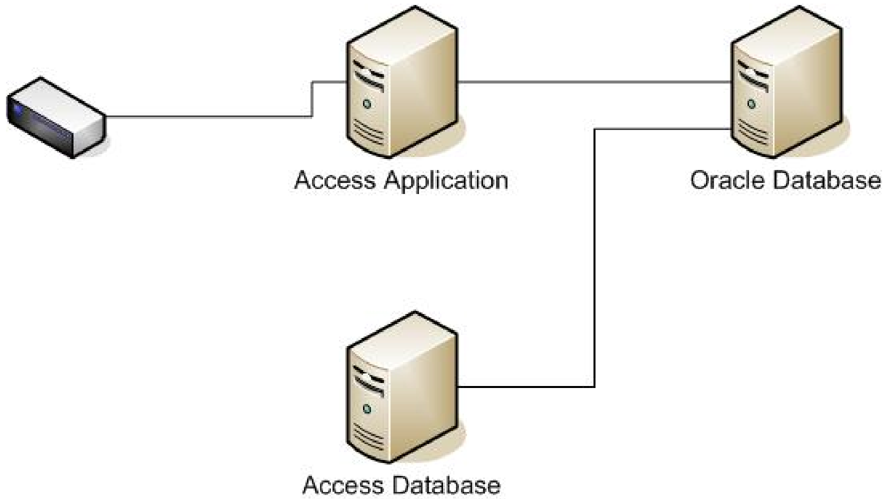
Database Integration System



The sole purpose of the data warehouse server is to extract data from the legacy database and insert that information into the Oracle database using a specified data format. The warehouse server is capable of data manipulation and low level calculations while the data is being passed from one database to the other.

The importance of the warehouse server is that it enables management to create reports that compare administration and vehicle maintenance to real time route and scheduling data.

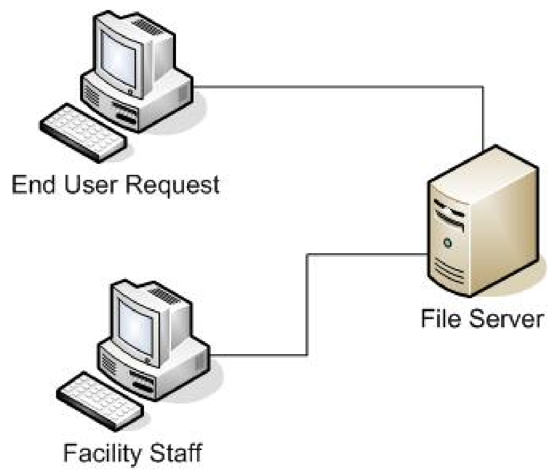
Facility Access Control System



The physical security access to the organization's facilities is managed and monitored through the access server. A proprietary badge reader was installed at designated entryways that grants authorized card holds entry through the door.

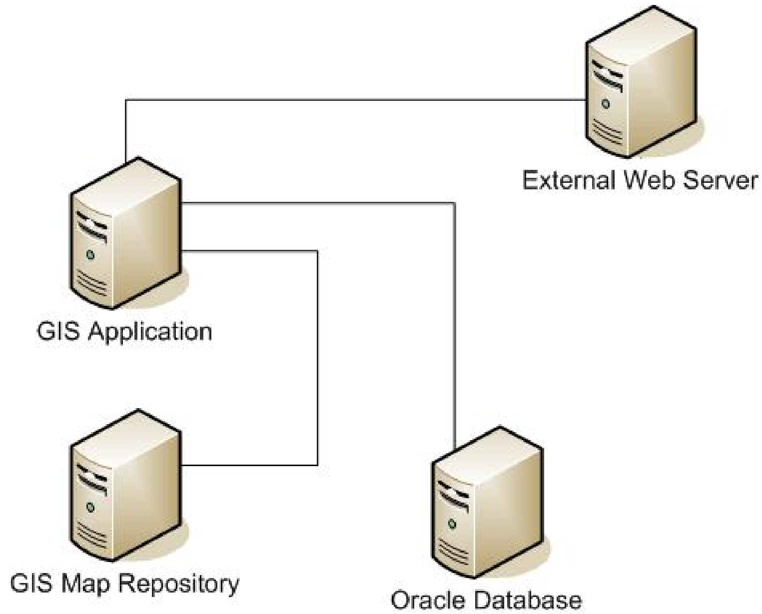
All successful and unsuccessful access attempts are recorded and housed in the access control database. Updated badge information is loaded from the Oracle database to the access control database.

Facility Task Management System



The means by which facility maintenance tracks requests and resources is through the Task Management system. A work ticket is submitted to a propriety database that resides on the file server. Facility management then assigns the ticket to the proper technician along with any other required equipment or supplies.

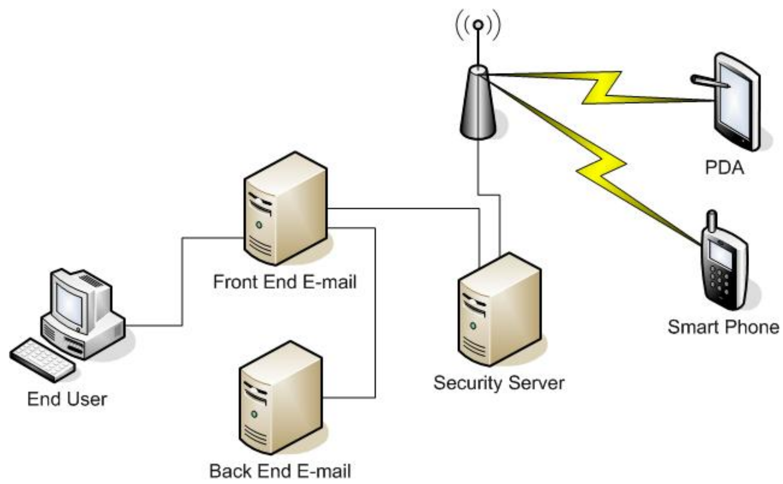
GIS System



The GIS system is crucial to the transit organization because of how dependent the organization is to the geography of the metro area. The GIS system enables the schedulers and planners in an efficient way of analyzing routes, bus stops, and rail lines.

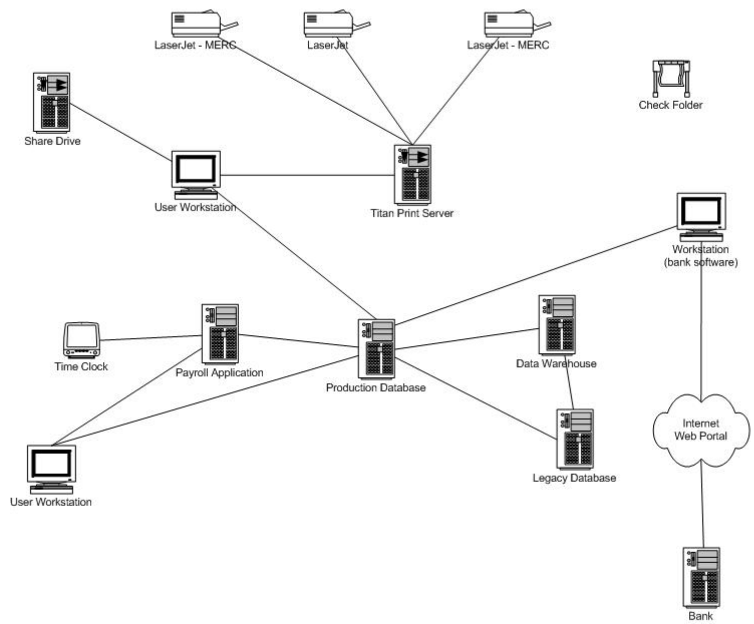
In addition, the information is available to the public through the Trip Planner application that resides on the external web server.

Messaging and Collaboration System



The messaging and collaboration system is based on the Microsoft Exchange infrastructure. Access to e-mail, calendar, conference room booking, and contacts are readily available both internally and externally to authorized users.

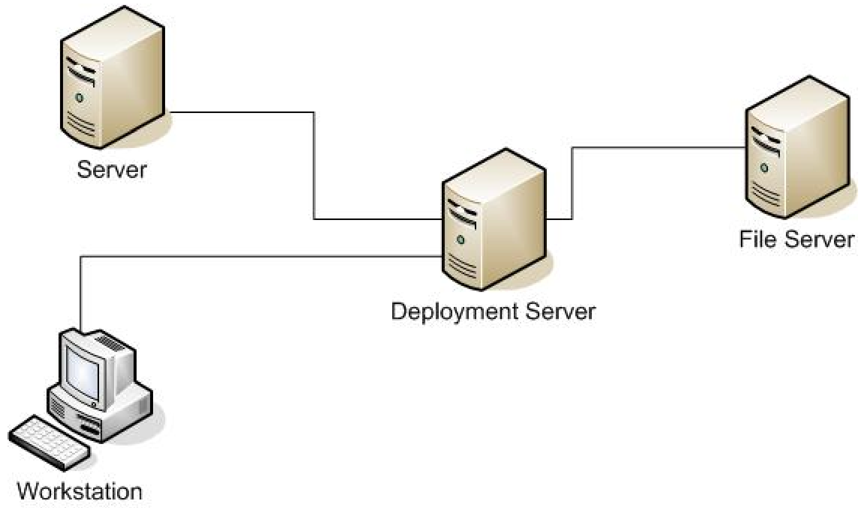
Payroll System



The organization's payroll system is complex and spans numerous server platforms. An advantage to the complexity of the system is that the required information for a payroll check does not permanently reside on one particular server.

On the other hand, this integrated security strategy creates numerous dependencies and points of failure. Therefore, the server team will have to be cautious when migrating a server that the system depends on.

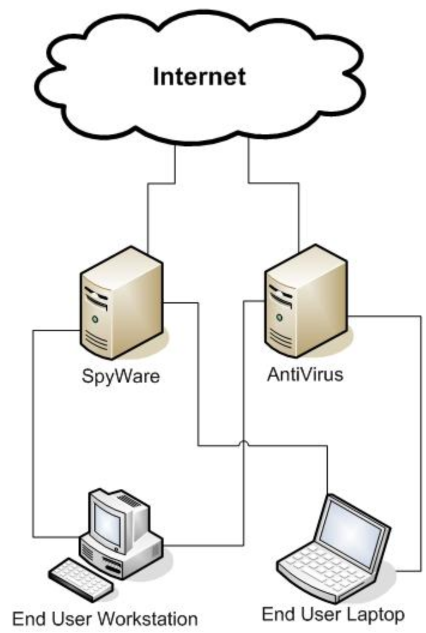
Remote Desktop Deployment System



The remote desktop deployment system is commonly used to push O/S and application updates to end user workstations. However, the deployment server is likewise capable of performing the same updates to Windows servers.

Update information and tracking is kept on the file server, while the actual update packages are housed on the deployment server.

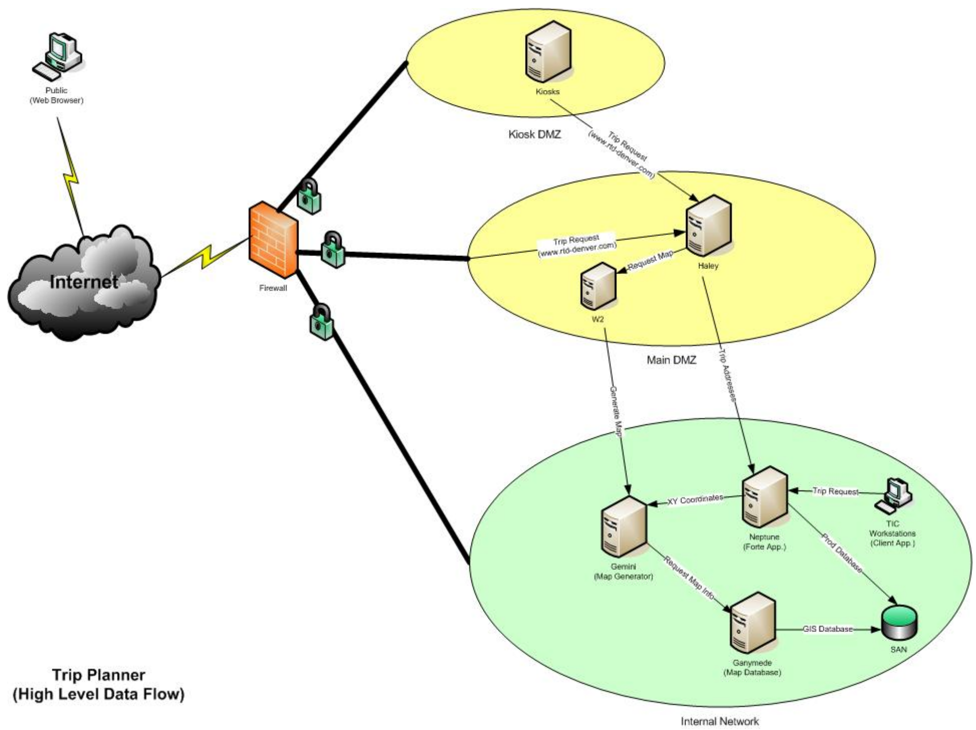
Spyware and Antivirus System



The architecture of the spyware and antivirus systems are very similar and also perform similar functions. However, the rates of new threats from spyware have been ahead of antivirus software developers. This is why the organization decided that specialized software was the best choice for the protection of the organization.

Automatic definition updates are received, via the Internet, and then are pushed at scheduled intervals to end user workstations and laptops.

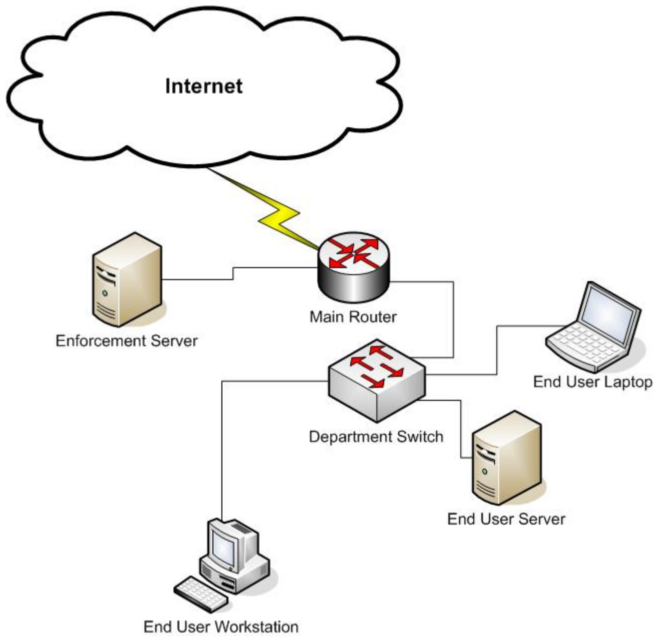
Trip Planner System



The Trip Planner is an internally developed system that is utilized in three different areas: Internet, Kiosks, and the internal call center. The system is extremely useful for customers looking to determine the overall routes needing to be taken in order to arrive at a destination for a specific time.

The complexity of the system is by the numerous points of failure at illustrated by the diagram above. The core of the system resides in a central database that is directly attached to a SAN storage unit.

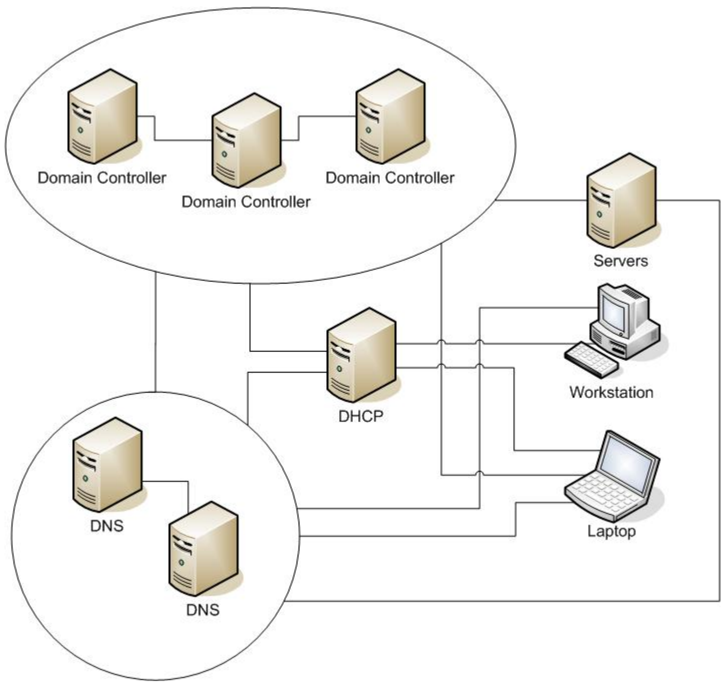
Web Policy Enforcement System



The Internet browsing policy for the organization is monitored and enforced through a central filtering server. The server is dual honed and monitors all TCP/IP connects for key patterns that are deemed unacceptable. If a pattern is recognized then the TCP/IP connection is terminated.

The server receives categorized updates of websites via the Internet which is then used as a black list. Customization of the black or white lists is possible through the management console.

Windows Domain System



The Windows Domain network is comprised of controllers, DNS servers, and DHCP servers. The only single point of failure is through the DHCP server. Therefore, IP lease policies are extendable if the end node is unable to contact the server for a new lease.

The redundancy of the Windows Domain enables server administrators the ease of migrating each server to the new architecture in a stair step methodology without impacting the user community.

APPENDIX: C

Project Design

- Server List and Migration Candidates
- Data Center Floor Plan
- Retired Server Hardware
- Product Selection Matrixes
- Statement of Work
- Server Performance Comparisons

Server List and Migration Candidates

NOTE: New Hardware (Non-Blade) = Green, New Blade Hardware = Yellow, Hardware 4 years or more = Red, Number of Reuse Hardware = 9, VM = VMware

	Hostname	Function	Function Description	Application Status	Hardware Status	Hardware Platform	Age
1	Access-Server	Facility door access	Lenal	Migrate to Blade (VM)	Retire Hardware	Prosignia 740 CQ	7
2	Adromeda	GIS Photo Development	ESRI for UNIX	Migrate to Blade (VM)	Retire Hardware	Workstation 500au Dec	6
3	Antares	E-Mail Anti Virus	Symantec	Maintain	Maintain	Workstation AP 550	5
4	Cad-lac	File (P&D)	Windows, Auto CAD Licenses	Migrate to Blade (FT)	Retire Hardware	Proliant DL380 CQ	3
5	CD Tower1	Legacy CD Share		Migrate to Pluto	Retire Hardware	CF28P5 Procom Tech	8
6	CD Tower2	Legacy CD Share		Migrate to Pluto	Retire Hardware	CDF21 Procom Tech	8
7	Centauri	TimeClock System	Cyber Shift	Migrate to Blade	**Reuse Hardware**	Proliant DL360 CQ	4
8	Cronos	HTTP Monitoring, Remote Access	SurfControl, RAS	Migrate to Blade	Retire Hardware	Proliant DL380 CQ	3
9	Den7	CAD/AVL	Management Workstation	Maintain	Maintain	Workstation B2600 HP	2
10	Deplan	Internal Legacy TripPlanner	WebTrans	Migrated to Neptune	Retire Hardware	2000 AXP DEC	10+
11	Deplan2	External Legacy TripPlanner	WebTrans	Migrated to Neptune	Retire Hardware	2001 AXP DEC	10+
12	Earth	E-mail	Exchange 5.5	Disperse work load	Maintain	Proliant DL360 HP	1
13	Electron	Windows Domain Controller	RTD.DOM Primary DC	Migrate to new hardware	Retire Hardware	Prosignia 740 CQ	5
14	Fax Sr.	Legacy Fax		Migrate to Genifax	Retire Hardware	Desktop P600 CQ	5
15	Fax Sr. Test	Fax migration test		Retire Funcation	Retire Hardware	Desktop P333 CQ	6
16	Galaxy	Backup	Legato Networker	Add local disk drives	Maintain	Proliant DL360 CQ	3
17	Ganymede	Database	Windows Oracle	Migrate to Neptune	**Reuse Hardware**	Proliant DL360 CQ	4
18	Gemini	GIS Map Creator	EASI Map	Migrate to Blade	Retire Hardware	Pro Workstation SP750	6
19	Genifax	Fax	Genifax	Maintain	Maintain	Proliant DL360 CQ	1
20	GFILanguard	Patch Management	GFI LanGuard	Migrate to Blade (VM)	Retire Hardware	Pro Workstation AP550	6
21	GFINetmgr	Farebox Collections		Migrate to Blade (VM)	**Reuse Hardware**	Workstation XW 4100 HP	3
22	Haley	Internet Front-End Web	Apache	Migrate to new hardware	Retire Hardware	Alpha 2000 Dec	10+
23	Hst1	CAD/AVL	Orbital SmartTrack, Oracle	Maintain	Maintain	9000D HP	10+
24	Hst2	CAD/AVL	Orbital SmartTrack, Oracle	Maintain	Maintain	9000D HP	10+
25	Hydra	Central Storage	SAN EVA 5000	Maintain	Maintain	Management Appliance II	2
26	Kiosk Server	Windows Domain Controller, Kiosk	KIOSK Primary DC, Kudos Central Server	Rack server	Maintain	Proliant DL380 CQ	4
27	Luna	Testing and Development	Mars and Neptune	Split Blade/stand alone	Maintain	Alpha ES40 CQ	1 Refurb

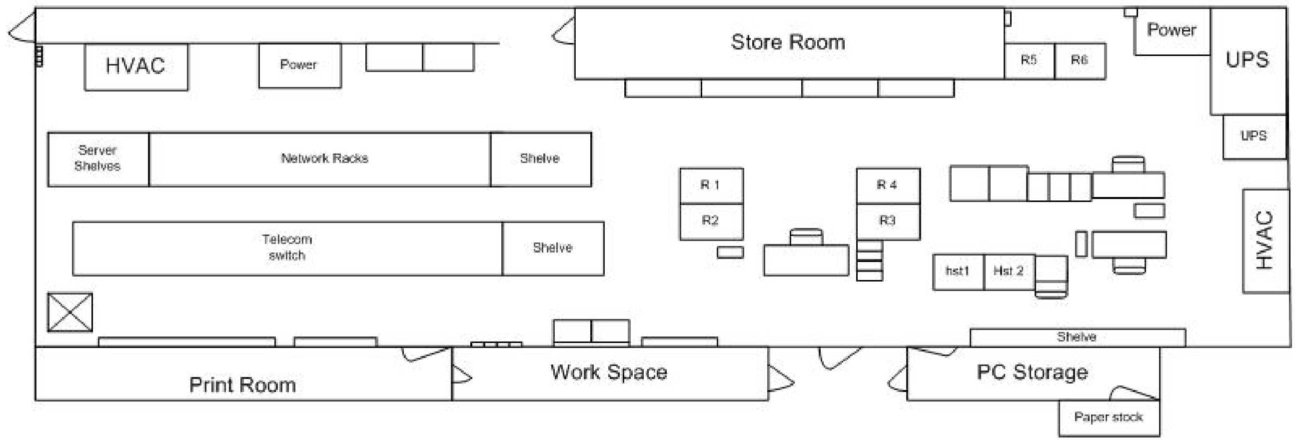
28	Mars	Legacy Database, Scheduling	Universe, CASS, File, Print, NIS, DNS, NTP	Migrate to Blade (Linux)	Retire Hardware	Alpha DS10 CQ	7
29	Mercury	Legacy Testing and Development	Mars and Neptune	Migrate to new hardware	Retire Hardware	Alpha 8200 Dec	10+
30	MSL5026	Tape Library		Maintain	Maintain	MSL5026 HP	1
31	Naos	Database	SQL	Migrate to Blade	**Reuse Hardware**	Proliant DL360 CQ	3
32	Naos Storage		Laser Fiche Storage	Move to SAN	Retire Hardware	Proliant Storage System U2	4
33	Neptune	Database, Scheduling, Application	Oracle, Forte, File, NIS, DNS	Migrate to Big Box (Linux)	Retire Hardware	Alpha ES40 CQ	3 Refurb
34	Neried	Database	Oracle data mover	Retire Funcation	Retire Hardware	Alpha 2100 Dec	10+
35	Neutron	Windows Domain Controller, File	RTD.DOM Secondary DC, Mac Share	Migrate to new Hardware	Retire Hardware	Proliant 5500 CQ	5
36	New Haley	Internet Front-End Web	Apache	Maintain	Maintain	Proliant DL360 HP	1
37	Odyssus	Windows DHCP		Migrate to DC	Retire Hardware	Prosignia 740 CQ	7
38	Old Access Control	Facility door access	Lenal	Migrate to Blade	Retire Hardware	Proliant ML570 CQ	5
39	Old Datastage	DataMart	IBM Datastage	Migrated to newer Hardware	Retire Hardware	Deskpro EN CQ	5
40	Old Trapeze	Legacy Planning and Scheduling	Trapeze	Migrated to Neptune	Retire Hardware	Deskpro 5133 CQ	9
41	Ontrack	E-mail Recovery	PowerControls	Migrate to Galaxy	Retire Hardware	Proliant 7000 CQ	7
42	Orion	Spam Filter	WebRoot	Migrate to Blade (VM)	Retire Hardware	Pro Workstation AP550 CQ	6
43	PARAPHONESRV	Call Queue Sign	Task Software	Migrate To New Hardware	Retire Hardware	Compaq Deskpro EN	5
44	Perseus	Anti Virus	Symantec	Migrate to Blade (VM)	Retire Hardware	Workstation W6000 CQ	3
45	Phobos	DataMart	IBM Datastage	Migrate to Blade (VM)	Retire Hardware	Proliant 580 CQ	6
46	Pluto	File (District)	Windows	Migrate to Blade (VM)	**Reuse Hardware**	Proliant DL360 CQ	1
47	Primavera			Migrate to Blade (FT)	**Reuse Hardware**	Workstation W6000 CQ	3
48	REPORTS2	Trapeze/Oracle Reports Sever	Crystal Reports, Spider Reports	Migrate To New Hardware	Retire Hardware	Compaq Workstation W6000	4
49	RTDCTX1	Citrix Server	Easter Seals Access to RTDADA.LOCAL	Migrate To New Hardware	Retire Hardware	Compaq ProLiant ML370	4
50	RTDDB1	Oracle Database Server	Trapeze Paratransit Client Database Server	Migrate To New Hardwar/ Migrate to Neptune	Retire Hardware	Compaq ProLiant ML530	4
51	RTDDC1	Windows Domain Controller	RTDADA.LOCAL Domain Controller	Maintain/Retire	Retire Hardware	Compaq ProLiant ML370	4

52	RTDDVM1	Automatic Passenger Counter	Central Manager	Maintain	Maintain	ML310 CQ	2
53	RTDFAX1	Fax	Trapeze Fax to Cab Companies	Migrate To New Hardware	Retire Hardware	Compaq ProLiant ML370	4
54	RTDSCHED1	Trapeze Schedule Server	Trapeze 4.61	Migrate To New Hardware	Retire Hardware	Compaq ProLiant ML370	4
55	RTDSTAT1	Automatic Passenger Counter	Reports	Maintain	Maintain	ML310 CQ	2
56	Sirius	Application	Oracle App	Migrate to Blade	**Reuse Hardware**	Proliant DL360 CQ	3
57	Titan	Windows Print	Windows	Migrate to Blade (VM)	**Reuse Hardware**	Proliant DL360 CQ	3
58	TSCensus	Software Auditing	Tally TSCensus	Migrate to Blade (VM)	Retire Hardware	Deskpro EN CQ	6
59	Vega	Intranet Testing and Development	Venus	Maintain	Maintain	Proliant 1600 CQ	5
60	Venus	Intranet	IIS, ColdFusion	Migrate to Blade	**Reuse Hardware**	Proliant DL360 CQ	3
61	Win2kterm	Dispatch Terminals	Windows Terminal Server	Migrate to Blade (VM)	Retire Hardware	Pro Workstation AP550	6
62	WW2	Internet Back-End Web	IIS, ColdFusion	Maintain	Maintain	Proliant DL380 HP	4
63	Xpressions	Voice Mail		Integrated in New Phone Switch	Retire Hardware		
64	Yelah	Backup Internet Front-End Web	Apache	Migrate to new hardware	Retire Hardware	Alpha 2100 Dec	10+

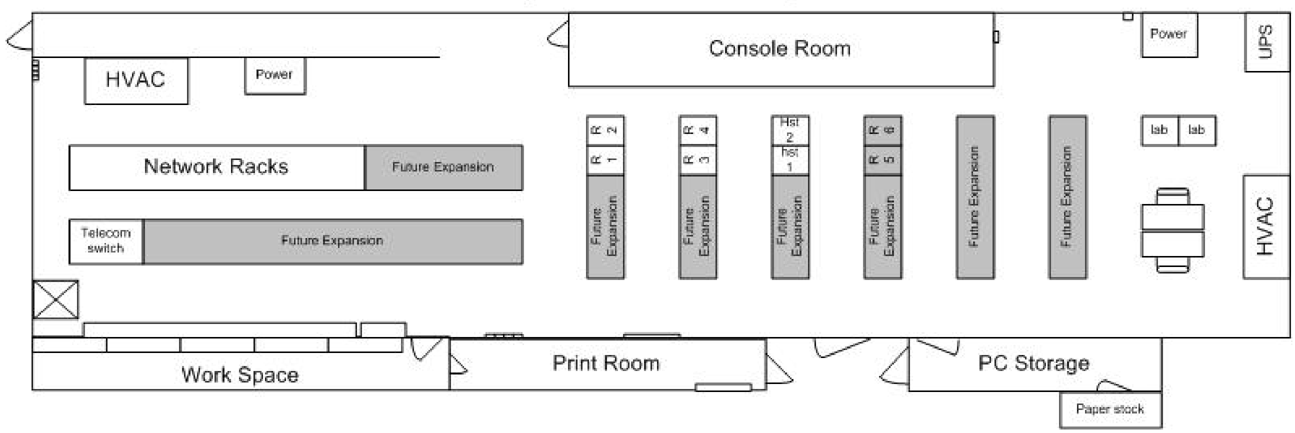
NOTE: New Hardware (Non-Blade) = Green, New Blade Hardware = Yellow, Hardware 4 years or more = Red, Number of Reuse Hardware = 9

Data Center Floor Plan

Previous Data Center Layout



Proposed Data Center Layout



Retired Server Hardware

	Hostname	Description	Reason	S/N	Platform
1	Access-Control	Legacy Facility door access	Migrated to New Platform	176097-001	Compaq Proliant ML570
2	Datastage	Legacy Datawarehouse Middleware	Migrated to New Platform	X034FHGZA177	Deskpro EN
3	Electron	Legacy Windows Domain Controller	Migrated to New Platform	D912CHM20004	Compaq Proliant 740
4	Fax Sr.	Legacy Central Fax	Migrated to New Platform	6027DGT2A358	Compaq Deskpro P600
5	Mercury	Legacy Database Development	Migrated to New Platform	NI55000ZGS	Digital Alpha Server 8200 5/300
6	Neutron	Legacy Windows Domain Controller	Migrated to New Platform	D833BRZ10084	Compaq Proliant 5500
7	Pluto	Legacy Windows File Server	Migrated to New Platform	D925CPK10089	Compaq Proliant 7000
8	Trapeze	Legacy Route and Schedule	Migrated to New Platform	6604HSG5Q011	Compaq Deskpro 5133
9	TSCensus	Legacy Asset Tracking	Migrated to New Platform	V103DY5ZA687	Deskpro EN

Product Selection

Blade Manufacturer Decision Matrix

Blade Servers: Comparison Columns

29 April 2005

	Dell Inc.	Fujitsu/Siemens Computers	Hewlett-Packard Co.	Hewlett-Packard Co.	IBM Corp.	IBM Corp.
	PowerEdge 1855	**PRIMERGY BX620 S2**	**ProLiant p-Class BL20/25p G3**	**ProLiant p-Class BL30/35p**	**BladeCenter HS20**	**BladeCenter HS40**
Validated	25 April 2005	25 April 2005	25 April 2005	25 April 2005	25 April 2005	25 April 2005
Processor(s) Supported	Intel Xeon	Intel Xeon DP	Intel Xeon/AMD Opteron	Intel Xeon/AMD Opteron	Intel Xeon	Intel Xeon MP
Processor Clock Speed (Hz)	2.8G, 3.0G, 3.2G, 3.6G	2.8G, 3.0G, 3.2G, 3.6G	3.0G, 3.2G, 3.4G, 3.6G	3.0G, 3.2G	2.4G, 2.8G, 3.0G, 3.2G, 3.4G, 3.6G	2.0G, 2.2G. 2.7G, 3.0G
Number of Processors Supported	"1-2"	"1-2"	"1-2"	"1-2"	"1-2"	"1-4"
Processor Cache, Maximum (bytes)	2M	2M	2M	512K	2M	512K
System Bus Speed (Hz)	800M	800M	800M	533M	533M	400M
RAM, Maximum (bytes)	12G	12G	8G	4G	8G	16G
Total Expansion Slots	1	2	4	2	2	4
Total Internal Drive Bays	2	2	2	2	2	2
Total Hot-Plug Drive Bays	2	2	2	0	2	2
Maximum Internal Storage Capacity (bytes)	600G	292G	292G	120G	373G	293G
Internal Storage Controller Type	Ultra320 SCSI	Ultra320 SCSI	Ultra3 SCSI	ATA	ATA/100 standard, SCSI optional	U160, U320 SCSI
Internal RAID Support	Yes	Yes	Yes	No	Standard	Optional
Enclosure	PowerEdge 1855 Enclosure	PRIMERGY BX600 Chassis	P-Class Server Blade Enclosure	P-Class Server Blade Enclosure	BladeCenter	BladeCenter

Enclosure Size	7U	7U	6U	6U	7U	7U
Maximum Number of Blades per Enclosure	10	10	8	16	14	7
Maximum Number of Blades per 42U Rack	60	60	40	96	84	42
Standard Interconnect	Ethernet Pass Through	One Gigabit Ethernet Switch connected to 20 internal blade server Gigabit Ethernet ports, three 1Gb uplink ports	Dual-port Fibre Channel Adapter	RJ-45 patch panel interconnect kit	Gigabit Ethernet	Gigabit Ethernet
Optional Interconnect	PowerConnect 5316M Ethernet Switch Module, Pass-Through Ethernet Module, Pass-Through Fibre Channel Module, Brocade Fibre Channel Switch Module, TopSpin InfiniBand Pass-Through Module	One additional Gigabit Ethernet Switch for redundancy, two 2Gb Fibre Channel Pass-Through modules, each with 10 ports	Patch panel with Fibre Channel Pass-Through, C-GbE Interconnect Kit with 4 to 8 ports, GbE Interconnect Kit with 4 to 8 ports, C-GbE2 Interconnect Kit with 12 ports, F-GbE2 Interconnect Kit with 12 ports	Patch panel with Fibre Channel Pass-Through, C-GbE Interconnect Kit with 4 to 8 ports, GbE Interconnect Kit with 4 to 8 ports, C-GbE2 Interconnect Kit with 12 ports, F-GbE2 Interconnect Kit with 12 ports	Two-port Fibre Channel Switch Module, four-port Gigabit Ethernet Switch Module, six-port Fibre Channel Switch Module	Two-port Fibre Channel Switch Module, four-port Gigabit Ethernet Switch Module, six-port Fibre Channel Switch Module
External Storage Type	NAS, SAN	SCSI, NAS, SAN, iSCSI	NAS, SAN	NAS, SAN	NAS, SAN	NAS, SAN
Power Supplies in Enclosure, Standard (watts)	2 + 2 @ 2,100	4 @ 1,200	External shared power supplies	External shared power supplies	2 + 2 @ 2,000	2 + 2 @ 2,000
Redundant Power Supplies	Optional	Standard	Optional	Optional	Optional	Optional
Hot-Plug Power Supplies	Standard	Standard	Standard	Standard	Optional	Optional
Redundant Cooling Fans	Standard	Standard	Standard	Standard	Standard	Standard
Hot-Plug Cooling Fans	Standard	Standard	Standard	Standard	Standard	Standard
Operating Systems Supported	Windows 2000 Server family, Windows Server 2003 family, Red Hat Linux family, SUSE Linux	Windows 2000 Server family, Windows Server 2003 family, Red Hat Linux, SUSE Linux	Windows 2000 Server family, Windows Server 2003 family, Red Hat Linux, SUSE Linux	Windows 2000 Server family, Windows Server 2003 family, Red Hat Linux, SUSE Linux	Windows 2000 Server family, Windows 2003 Server family, Red Hat Linux, SUSE Linux	Windows 2000 Server family, Windows 2003 Server family, Red Hat Linux, SUSE Linux
Server Management	OpenManage, standard	ServerView, standard	Systems Insight Manager 7, standard	Systems Insight Manager 7, standard	IBM Director, standard	IBM Director, standard

Remote Management	DRAC/MC, standard	RemoteView, standard	Integrated Lights-Out Advanced, standard	Integrated Lights-Out Advanced, standard	Integrated System Management Processor, standard	Integrated System Management Processor, standard
Provisioning Software	Altiris Deployment Manager, optional	RemoteDeploy, optional	ProLiant Essential Rapid Deployment Pack, optional	ProLiant Essential Rapid Deployment Pack, optional	IBM Remote Deployment Manager, optional	IBM Remote Deployment Manager, optional
Blade Server Entry Price (US$)	3,547 with two processors	3,300 with two processors	4,299 with two processors	2,999 with two processors	1,949 with two processors	9,126 with four processors
Chassis Entry Price (US$)	2,999	6,935	1,499	1,499	1,999	1,999
Standard Warranty	Three years, on-site, NBD, parts and labor	Three years, on-site, NBD, parts and labor	Three years on-site parts and labor	Three years on-site parts and labor	Three years parts and labor	Three years parts and labor
TOTAL POINTS	10	10	10	9	11	9

Product Selection (con’t)

On-Site Demonstrations: IBM vs. HP Blade Servers

Full mgt. software (Common advantages to both)

- Each provide “Enterprise” Chip blade (PARISC and Power)
- Both have Intel EM64T Zeon and AMD Opteron option
- Both have management port (IMP/iLO/BIOS level remote console access

IBM Pros

- Altiris software option
- InfiniBand passive shared backplane (faster/more flexible)
- Can cluster via InfiniBand
- Dual backplane
- Viable Power/Unix/Oracle blade option
- Can support “mixed” blade (i.e. Zeon/Opteron/Power)
- Failover between blade servers.
- Having a floppy/CD/USB in BladeCenter
- More of a standard design/connection standards. Possibility of other vendor blades able to plug into BladeCenter.
- High density blade server.
- More choices for interconnects

IBM Cons

- Heat issues with SCSI drives

HP Pros

- Already have iLO on servers- can manage them, has BIOS console access via the Blade Management station.
- Already have Proliant Universal drives- can move them to blade servers

HP Cons

- cPCI switched backplane.
- Can’t cluster due to reliance on Ethernet.
- Single backplane.
- PARISC going away, no “enterprise” chip option.
- Blades must be the same per chassis.
- No integrated Floppy/CD/USB. Needs a laptop and special cable.
- Non-integrated Power supplies.

Statement of Work

Blade Server SOW
May 27, 2005

Introduction
RTD requires twelve new servers located at two different locations for various projects such as FasTracks, ERP, ADA, Disaster Recovery and server consolidation. The RTD IT technical staff has done many hours of research, testing and demonstrations on IBM, HP and Fujitsu blade server technology over the past two months. Our conclusion is that the IBM Blade Center is the right choice for RTD.

The RTD requires two IBM Blade Center chassis of which one will be located at our main data center at 1900 31st Street, Denver and our FasTracks office located at 1560 Broadway.

Each chassis will require redundant 2000 watt power, KVM, Cisco Ethernet switches and Optical pass-thru modules for improved reliability.

All blades will be HS20 blades with two 3.6 Ghz Xeon with EM64T CPU's, 4GB of RAM, mirrored 73GB 10k SCSI hard drives, Fibre Channel Expansion Card for SAN connectivity. See detailed parts list below.

Hardware Requirements
The following hardware specifications are for the blade center chassis and blade server. RTD requires two IBM BladeCenter chassis, and six IBM blade servers per chassis, each of which will follow the hardware specifications list below respectively. In addition, two server rack cabinets are required each with the specifications as listed below.

IBM BladeCenter Chassis Specifications:

Qty.	Part no.	Description
1	86773XU	BladeCenter Warranty service upgrade; 3 year onsite repair 24x7x2 hour
2	02R9080	IBM eServer BladeCenter (TM) Optical Pass-thru Module
2	26K6547	Cisco Systems Fiber Intelligent Gigabit Ethernet Switch Module for IBM eServer BladeCenter
1	26K4816	IBM eServer BladeCenter 2000W Power Supply Modules
1	48P7055	IBM KVM/Redundant Management Module Option

2	73P5992	IBM eServer BladeCenter (TM) Optical Pass-thru Module SC Cable (1.5M)

IBM Blade HS20 Server Specifications:

Qty.	Part no.	Description
1	884345U	BladeCenter HS20 Warranty service upgrade; 3 year onsite repair 24x7x4 hour
2	13N0696	3.6GHz 800MHz 2MB L2 Cache Xeon DP with Intel EM64T
1	26K4841	IBM eServer BladeCenter SFF Fibre Channel Expansion Card
2	90P1313	73GB SFF NHS U320 10K SCSI HDD
1	26R1022	Option, Integrated SCSI Mirroring in Blade Server
1	29R5396	RTS - 3 year Remote Technical Support for xSeries, IBM Director, Windows and Linux
2	73P2866	2GB (2x1GB) PC2-3200 ECC DDR SDRAM RDIMM Kit
1	09N8043	Remove standard memory

IBM Blade HS40 Server Specifications:

Qty.	Part no.	Description
1	883971X	BladeCenter HS40 883971X
1		Processor: 3.0 GHz/400 MHz/ 4MB L3 Cache Upgrade with Xeon MP (Standard)
1		Standard I/O feature: Each blade server contains four Gb Ethernet ports which are routed to switch modules which can be selected with the BladeCenter enclosure. (Standard)
3	13N0654	Additional processors: 3.0GHz 4MB L3 Cache Xeon MP
4	33L5040	Memory: 2GB PC2100 ECC DDR SDRAM RDIMM
1	13N2203	Expansion cards: IBM eServer BladeCenter Fibre Channel Expansion Card
1	25R6906	EIDE Hard disk drive 1: IBM BladeCenter 40GB 5400rpm HS20, JS20
1	25R6906	EIDE Hard disk drive 2: IBM BladeCenter 40GB 5400rpm HS20, JS20
1	69P9518	IBM ServicePac® for warranty and maintenance options: Warranty service upgrade; 3 year onsite repair 24x7x4 hour
1	29R5400	Remote technical support services: RTS – 3 year Remote Technical Support for xSeries, IBM Director, Windows and Linux with VMware

Server Rack Specifications:

Qty.	Part no.	Description
1	930842S	NetBay42 Enterprise Rack
1	32P1031	1U Flat Panel Console /w keyboard
2	37L6866	NetBay PDU (US)
2	94G6670	Blank Filler Panel Kit

Service and Support Requirements

IBM 24x7 x 2hour on site technical and hardware support is required for all components including IBM Director software.

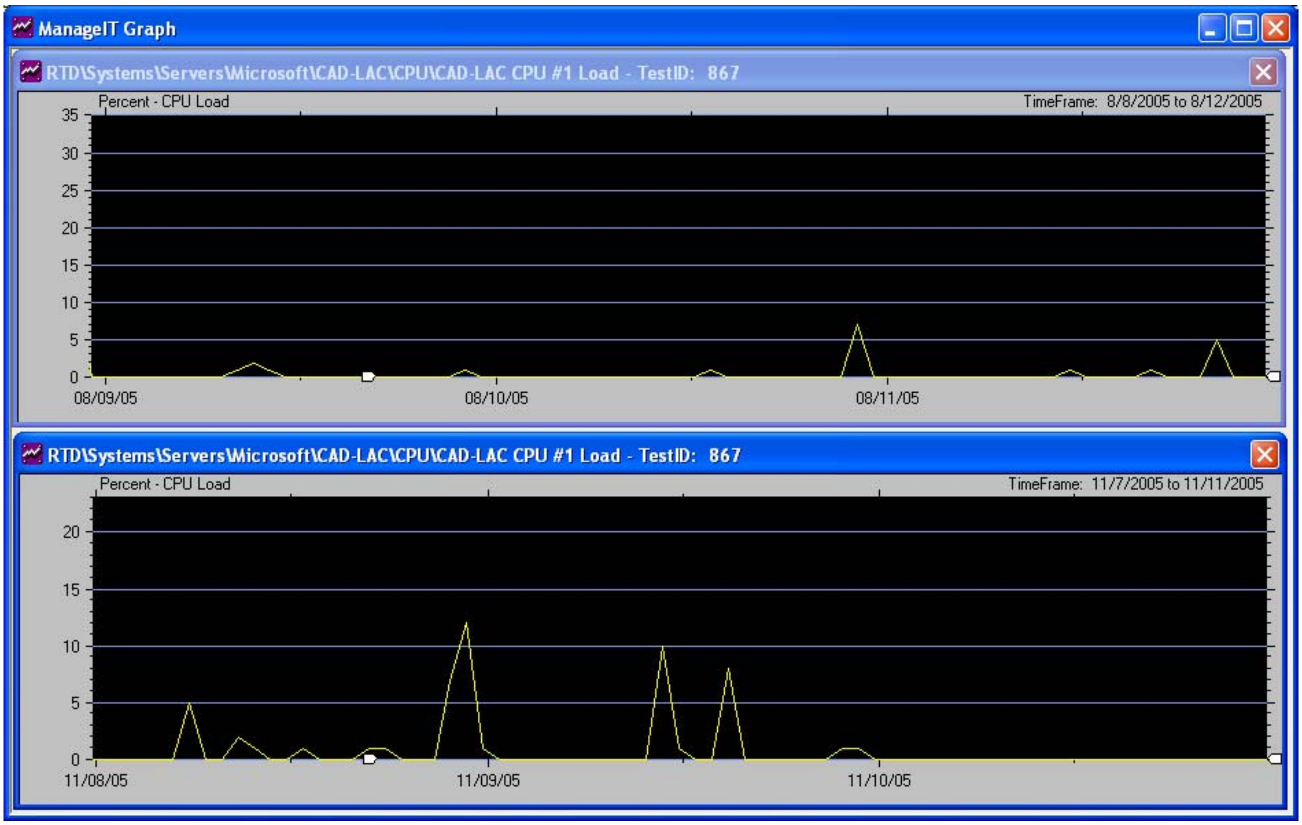
Setup and Training

The RTD requires the winning bidder to deliver and setup blade chasses as well as setup and test IBM Director for all components. Setup should also include recommendations on proper cooling techniques for the blade chassis at both locations.

Furthermore, the RTD is requesting three days of on site training for up to five administrators on the following:

1. IBM Blade server hardware
2. IBM Director including server deployment, and recovery.
3. Setup and integration of IBM Director.
4. IBM virtual machine manager functions

Server Performance Comparisons



The CPU utilization graph illustrates the percentage usage for the AutoCAD server, before and after the migration to a virtual server. The server was selected as underutilized, shown in the top graph in the monitoring range of a week. Notice that the CPU never spiked over ten percent, with only one spike above five percent. However, the AutoCAD application resided on standalone server, which was included in the maintenance agreement.

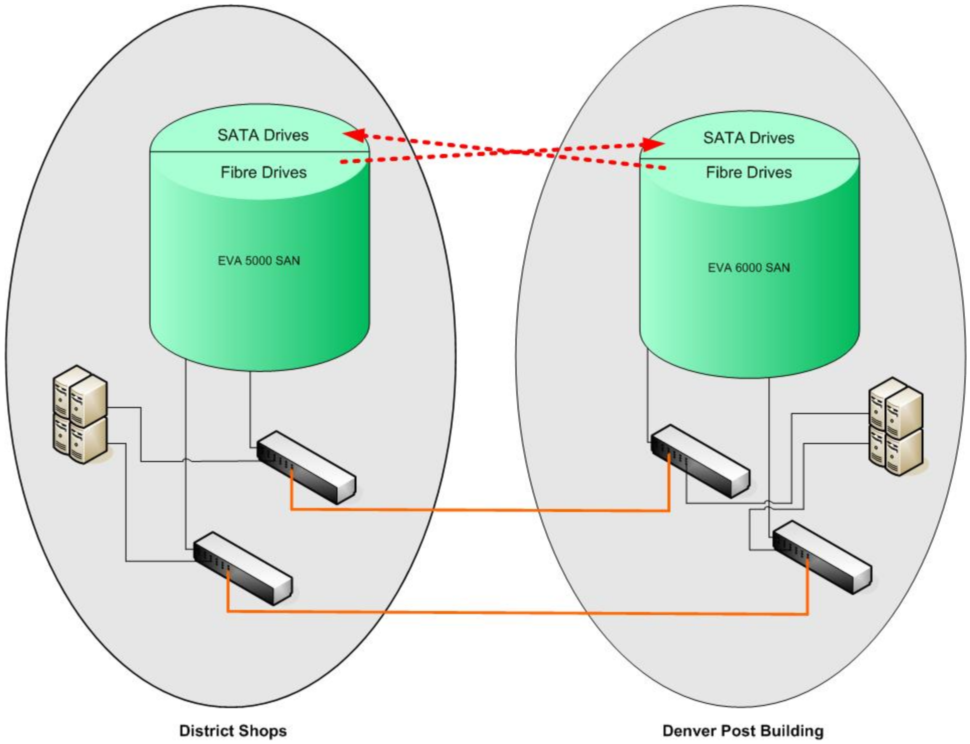
Upon, the server being migrated to a virtual machine the virtual CPU utilization was better allocated, with spike near fifteen percent. The change occurred because the VMware manager was used to restrict the unused processor time.

APPENDIX: D

Future Projects

- ENTERPRISE SAN REPLICATION
- ENTERPRISE SYSTEM INFRASTRUCTURE

Enterprise SAN Replication

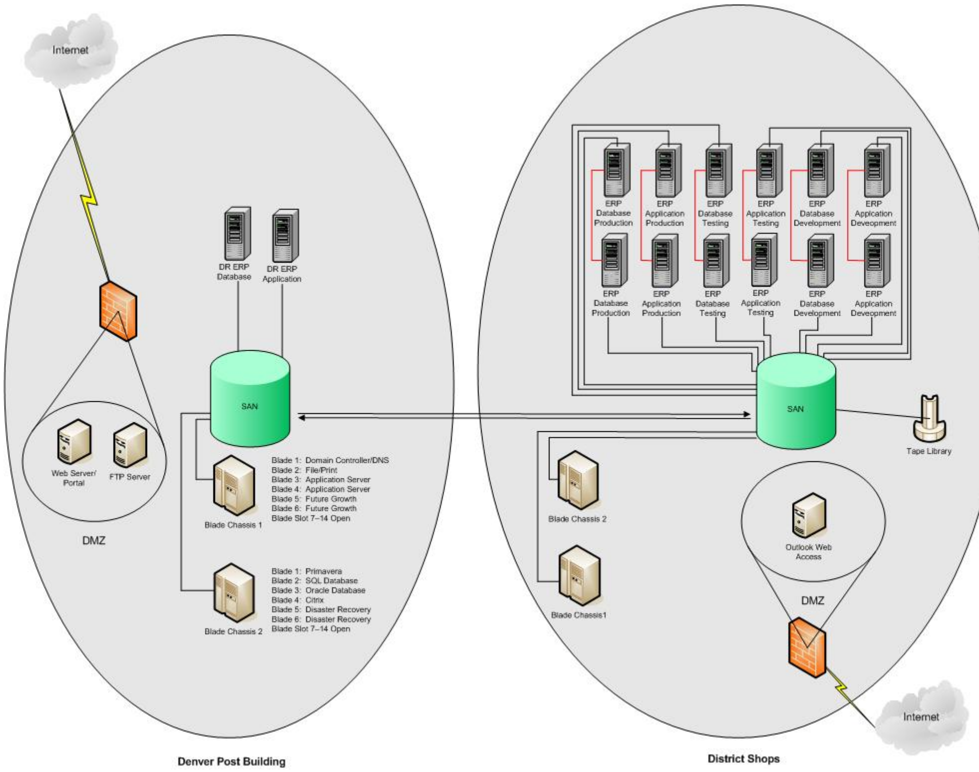


The enterprise SAN architecture takes advantage of the Light Rail expansion project office located geographically distant from the main data center. The project office is fitted with a local SAN array from the same manufacturer.

The asynchronous storage replication, on a block level, would occur over single mode fiber. The replicated storage area on the remote SAN would be made up of less costly SATA drives. Even though the drives are lower quality and slower, this will not be a risk since RAID 5 would be used along with asynchronous block writes.

The only added expense would be the extra backup SATA drives and the replication software provided by the SAN manufacturer. The infrastructure would be in place regardless of the proposed SAN project. Therefore, capitalizing on the circumstances of the organization would introduce a resilient enterprise network.

Enterprise System Infrastructure



The future system infrastructure for the organization would have the capability of a full featured resilient network, including real time fail-over between the two data centers. Based on the benefits of the server consolidations and SAN replication projects, wide area clustering could be introduced.

Each data center would be self reliant, and also have the capability of servicing the other data centers responsibilities in the event of unforeseen circumstances. Less critical systems that can tolerate short term outages would be brought back on-line through server imaging and/or virtual machines.

ENDNOTES

Altiris Server & Infrastructure

http://www.altiris.com/products/server/index.asp

The manufacturers' product catalog details the features and specifications of the product. Also, white papers and case study discuss the advantages and application of the technology.

Gartner Group, Inc.

http://www.gartner.com/Init

The firm is a leading provider of research and analysis about the global information technology industry.

IBM BladeCenter Chassis

http://www-03.ibm.com/servers/eserver/bladecenter/chassis/more_info.html

The manufacturers' product catalog details the features and specifications of the product. Also, white papers and case study discuss the advantages and application of the technology.

IBM Blade Servers

http://www-03.ibm.com/servers/eserver/bladecenter/blade_servers_overview.html

The manufacturers' product catalog details the features and specifications of the product. Also, white papers and case study discuss the advantages and application of the technology.

IBM Director

http://www-03.ibm.com/servers/eserver/xseries/systems_management/director_4.html

The manufacturers' product catalog details the features and specifications of the product. Also, white papers and case study discuss the advantages and application of the technology.

IBM Mainframe

http://www-03.ibm.com/servers/eserver/zseries

The manufacturers' product catalog details the features and specifications of the product. Also, white papers and case study discuss the advantages and application of the technology.

IEEE Spectrum

http://www.spectrum.ieee.org/dec05/inthisissue

IEEE Spectrum magazine is the flagship publication of the IEEE. It is a monthly magazine for technology innovators, business leaders, and the intellectually curious. Spectrum explores future technology trends and the impact of those trends on society and business.

VMware ESX Server

http://www.VMware.com/products/esx/

The manufacturers' product catalog details the features and specifications of the product. Also, white papers and case study discuss the advantages and application of the technology.

Webopedia

http://www.webopedia.com

An online computer dictionary for computer and Internet terms and definitions.