After-Initiative Report (AIR)

Server Consolidation for Advanced Leveraging of Equipment

Supporting Multi-National Corps Iraq/C6
Server Virtualization

United States Air Force
Global Cyberspace Integration Center
Langley AFB, VA 23665

26 July 2007

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DEPARTMENT OF THE AIR FORCE
GLOBAL CYBERSPACE INTEGRATION CENTER
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26 July 2007

MEMORANDUM FOR SEE DISTRIBUTION LIST

FROM: USAF GCIC/MIO
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SUBJECT: Server Consolidation for Advanced Leveraging of Equipment (SCALE) After-Initiative Report

The enclosed After-Initiative Report is forwarded for your information and/or action as appropriate. This document summarizes the recently completed Server Consolidation for Advanced Leveraging of Equipment (SCALE) initiative.

If you have questions concerning any information contained in this document, please contact Maj Lanny Greenbaum DSN 312.575.8738 Comm 757.225.8738.

Joseph L. Lenertz, Col, USAF
Chief, Operations Division

Attachment: Server Consolidation for Advanced Leveraging of Equipment (SCALE) After-Initiative Report, 26 July 2007

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EXECUTIVE SUMMARY

Mission Statement. Server Consolidation for Advanced Leveraging of Equipment (SCALE) evaluates VMware ESX Server 3.0.1 virtualization software for use at Camp Victory, Baghdad, Iraq. Global Cyberspace Integration Center (GCIC) personnel and Multi-National Corps - Iraq, C6 (MNC-I/C6) synchronized efforts to reduce information technology (IT) equipment, power, space, and heating, ventilation, & air conditioning (HVAC) demands while increasing system redundancy and scalability for Non-Secure Internet Protocol Router Network (NIPRNet), Secure Internet Protocol Router Network (SIPRNet), and Combined Enterprise Regional Information Exchange System (CENTRIXS) in direct support to 8,000 Coalition warfighters.

Course of Action. The GCIC/MIO (formerly the Command and Control Intelligence, Surveillance, Reconnaissance Battlelab (C2ISRB)) evaluated the server virtualization technology in three phases. In Phase I the team virtualized the common server environment reducing the environment from nine servers to two. In Phase II the team transferred the legacy system to the new virtualized hardware and matched the MNC-I/C6 configuration. In Phase III the team evaluated the impact of a physical failure on the virtual environment.

Results. VMware shrinks the server count 84% from 56 to nine with power savings of 78%. This provides an estimated $16K a year in electrical cost avoidance alone. VMware-based solution also weighs 48% less, reclaims 57% rack space, and saves 80% on current HVAC demands.

Recommendations. Server virtualization significantly impacts system administration by reducing resource allocation and increasing capabilities. Virtualization reduces the costs of the Air Operations Center (AOC) server environment with a smaller, more efficient solution. Recommended that virtualization be implemented in existing server systems throughout the Air Force and Department of Defense (DoD).

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SECTION 1: DEMONSTRATION MISSION STATEMENT

1.1 Purpose

SCALE seeks to reduce power, space, and HVAC demands while increasing system redundancy and scalability for NIPRNet, SIPRNet, and CENTRIXS by evaluating server virtualization using VMware. SCALE focuses specifically on feedback concerning automatic fail-over while increasing system survivability.

1.2 Background

SCALE was initiated in response to server area challenges faced by the MNC-I/C6. MNC-I is a tactical unit responsible for command and control operations throughout Iraq divided into six areas of responsibility (AORs) maintained by forces from 26 countries. The C6 unit in Baghdad provides network resources to over 8,000 Coalition personnel. In January 2007, personnel from MNC-I/C6 approached the GCIC (formerly C2ISRB) for assistance evaluating server virtualization technology.

Over time, MNC-I/C6's server infrastructure grew to consist of numerous servers thereby creating a severe deficiency of physical space (including lack of test bed and lack of spare manpower or network capacity to evaluate virtualization). Given the location's hash environment, the cooling requirement for that location was at a breaking point. The MNC-I/C6 also faced an upcoming Baghdad troop surge that would further tax the situation.

Limited resources existed for MNC-I/C6 personnel to standup and maintain a test bed environment to evaluate server virtualization. In addition, MNC-I/C6 needed to expand redundancy of critical components and viewed server virtualization as a possible solution.

1.3 Virtualization Overview

Virtualization consolidates many physical servers into fewer servers. Each physical server is reflected as a virtual machine residing on a virtual machine host system. This is also known as a physical-to-virtual (P2V) transformation. Typically, a server supports a single application using only a small fraction of processing power. When a new application is brought online, a new server is added taxing electrical, cooling, and real estate resources.

Server virtualization utilizes unused processor cycles to power virtual machines. Virtualization also lowers power consumption, heat generated, and a smaller overall footprint needed for server infrastructure. These recapitalized resources provide a more robust environment, easier disaster recovery, and increased flexibility not possible in a tradition environment.

1.4 Benefits of Virtualization

Virtualization provides the following benefits:

- Taps into lost processing capabilities by turning a single function server into a multi-functional server
- Harnesses unused server processing power with no performance degradation
- Conserves valuable resources by decreasing space, power, and HVAC requirements
- Increases redundancy, i.e., increased survivability through redundancy

1.5 Length of Time

The SCALE-I evaluation initiative commenced in January 2007 and completed in June 2007.

SECTION 2: COURSE OF ACTION

2.1 Strategy

The SCALE team established the following three phased approach for evaluation. A detailed outline of the process is available in **Section 5.1** .

Phase I: Create a virtual environment

- Reduce nine servers to two servers
- Ensure virtual environment is stable
- 'Capture' virtualized baseline

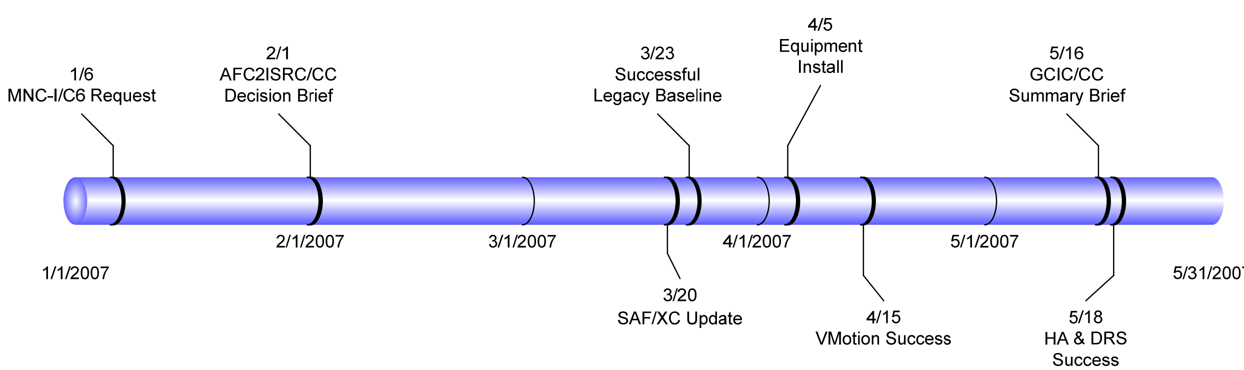
Phase II: Migrate legacy system

- Setup/mirror/copy virtualized environment to new servers
- Install/optimize storage area network (SAN) environment
- Test active directory (AD), Oracle, and web application hot swap for application fail-over

Phase III: Evaluate impact of physical failure of virtual environment

- Test complete system failover (worst case scenario)
- Dynamic load balancing

2.2 Schedule



Date	Event
6 Jun 06	AOC server virtualization idea submitted Barry Wheelbarger, (C2ISRB)
Late Fall 06	Initial VMware GSX evaluation for proof of concept (no sponsor)
Jan 07	MNC-I/C6 personnel requested assistance evaluating VMware 3.0.1 ESX
13 Jan 07	Initial teleconference with MNC-I/C6 personnel
1 Feb 07	Decision brief presented to AFC2ISRC/CC
20 Mar 07	SAF/XC end of day update
23 Mar 07	Successful virtualized baseline of legacy equipment
5 Apr 07	New server and SAN install

15 Apr 07	Successful VMotion demonstration (on-the-fly migration of a running process to a different physical host while maintaining service)
16 May 07	Summary briefing to GCIC/CC
18 May 07	Successful evaluation of robust High Availability (HA) and Dynamic Resource Management (DRS)
Jun/Jul 07	Delivery of MNC-I/C6 virtualization equipment; begin in-theater testing
19 Jul 07	SAF/XC brief and demo
Jul/Aug 07	Anticipated theater roll-out (MNC-I/C6)

2.3 Resources

Equipment	
2x - Dell 6950 PowerEdge Servers, VMware ESX 3.0.1 virtualization and Virtual Center management software	$100.3K
EMC CX-320 1 TB SAN	$62K
Keyboard, Video, Mouse (KVM)	$2.8K
Electrical	
Install additional circuits	$1K
Budget Total:	**$165K**

* This table reflects additional equipment needed (not a complete equipment listing)

Additional Equipment Utilized
2x - Dell 1855 PowerEdge blade servers and chasis for VMWare Virtual Center 2.0 management software, AD controller and DNS
Dell Precision M70 notebook, 2x Dell 24 inch LCD monitors (portrait mode)
2x Linksys GigE 16 port switches (unmanaged)**

** Non-standard IP schemas will require special switch/port configuration by NetOps

2.4 Manpower

GCIC (formerly C2ISRB) personnel devoted 816 man-hours over a six month period averaging 42.2 man hours a week in a three-man shop.

2.5 Assessment

A detailed outline of the assessment process and results is available in **Section 5.1** .

Phase I: Create a virtualized legacy TBMCS 1.1.4 B3 Sup 10 – learn virtualization

a. Manually build static virtual machines (backend storage needed for additional functionality)
b. Order equipment to match MNC-I/C6 install

Phase II: Install operational equipment (SAN, 6950s)

a. Virtual server migration (V2V) to SAN; import legacy virtual environment
b. VMotion testing
c. HA/DRS Testing; Software deficiency identification/resolution
    i. Domain Name Service (DNS)/Internet Protocol (IP) connectivity
    ii. Migration failures
    iii. Maintenance Mode
    iv. Licensing issues
d. Virtual Machine (VM) cloning
    i. SAN tuning
    ii. Host Bus Adapter (HBA) troubleshooting
e. P2V using VM Converter (Warfighter to Warfighter Forwarder (WWF))

Phase III: Evaluate impact of physical failure of virtual environment

a. DRS issues
b. HA issues

SECTION 3: LESSONS LEARNED

The following provides some of the best practices and lessons learned during the evaluation.

3.1 Pre-Installation

- Ensure IP address schema is captured prior to the first server installation.
- Additional IP addresses are required for VMotion capability.
- For improved performance, provide pointers in DNS for ESX servers.
- Given the number of servers managed, consider using a separate console management station as opposed to standard KVM.

3.2 Best Practices

- Understand the difference before migration and cloning. If the original virtual machine is to be left intact, a migration should <u>not</u> be performed. The VMs should be **cloned** onto the SAN and the local data storage left intact. This is critical for initial conversion to virtual world.
- Highly recommend <u>NOT</u> using dynamic host configuration protocol (DHCP) for ESX servers. DHCP tends to not release the IP address upon lease expiration and has a much higher potential for IP address conflicts.
- Having Exchange, AD and web services on a VM allows them to be moved to a secondary location while performing preventative or emergency maintenance. This feature eliminates service downtime while performing Preventive Maintenance Inspection (PMI) actions. Austere or deployed locations find this extremely beneficial given increased PMI demands due to sand, dust, etc.
- Isolated software deficiency which trigged targeted code review and subsequent re-write by VMware. Meticulous evaluation identified multiple issues which impact efficient deployment in the military environment. VMware used these findings to define new best practices for two-host systems. VMware customers worldwide will benefit from these efforts through the next software release.
- Use of this technology leads to more efficient server farm management and maintain of the server baseline.
- There was a 16°F difference between the virtual and traditional environment (separate racks).
- Utilize DRS rules when 3 or more ESX hosts are utilized to ensure critical services (primary) are never auto-balanced on the same physical server.
- Avoid the temptation to manually load balance or fence server resources. After defining resource thresholds, VMware has to ability to completely optimize its environment based on priority and historical trends to always be in the best possible state, managed behind the scenes with little, if any impact to the end user.
- Enable read and write caching in a memory balanced fashion to improve SAN response, console responsiveness, migration, and failover times. Since VM implementation of SAN resources is heavier on the read side, 256 MB of RAM was dedicated to each read and write cache. This exceeds the current practice of allotting 100 MB, but proved beneficial.
- Connect ESX servers using fully qualified domain name (FQDN) instead of the IP address. Connection method dictates how these machines appear on the Virtual Infrastructure Client (VIC). Use descriptive names such as ESX1950.DOMAIN or ESX6850.DOMAIN for easy resolution.

- Consider adding virtualization software to the Preferred Products List (PPL) along with centralized license management (i.e., how the Air Force manages Oracle licensing).
- Proceed with server virtualization in support of GCIC's Constellation Development Environment (CDE) and later Defense Research and Engineering Network (DREN).
- Uncovered Virtual Center software order error that accidentally matched ESX 3.0.1 with incompatible Virtual Center management software. The same error was discovered with MNC-I/C6's order and quickly rectified before shipment to Iraq saving an estimated 2-3 weeks of downtime. The identification of this error initiated changes within Dell's system to ensure this issue does not happen in the future

3.3 Virtualization Roadblocks

- Recommend having one AD Controller/DNS and Virtual Center/Licensing Server on dedicated, non-virtualized servers or blades.
- Process intensive applications may not be viable candidates for server virtualization. VMWare has an effective evaluation process to identify most viable virtualization candidates.

SECTION 4: CONCLUSIONS AND RECOMMENDATIONS

The SCALE initiative sought to demonstrate server virtualization for use in a military environment.

Virtualization of the MNC-I/C6 servers provides higher server utilization, which enhances performance and reduces server cost and footprint. Server reliability is created as virtual servers span enterprise hardware, creating redundant server arrays (meaning the loss of a single server does not imply the loss of a server service).

SCALE benefits the warfighter by providing a significantly reduced server footprint including decreased space, power, and HVAC demands as well as increased survivability through redundancy. For MNC-I/C6, virtualization will significantly ease the burden on existing equipment, minimize PMI downtime, and significantly improve system performance and network resiliency.

SCALE pilot program was reviewed and utilized by the ACC/A6N staff prior to initiating their own virtualization endeavors.

Effort identified best practices for two-host systems and meticulous testing lead to direct software improvement to the VMware product.

A hybrid approach (virtual, non-virtual) may be the best choice to integrate processor intensive applications.

Recommendations:

There are many possible employments for server virtualization including: Network Operations and Security Center (NOSC) and Network Control Center (NCC) environments, tactical/deployable equipment, and Virtual Air & Space Operations Center (AOC).

After showing such promise, the Air Force should further evaluate server virtualization for Enterprise use and develop appropriate TTP and training plans.

SECTION 5: Appendices

5.1 Test Plan Overview

The following details the test plan processes and results. The lessons learned in **Section SECTION 3:** provide additional insight into the best practices when completing server virtualization.

5.1.1 Phase I

5.1.1.1 Manually build static virtual machines (backend storage needed for additional functionality)

A call for assistance came in from the field with a critical MNC-I/C6 warfighter need and began a full redirect on exiting SCALE initiative. Dell and VMware representatives were contacted for acquiring VMware ESX in support of the SCALE-I initiative. Utilizing existing equipment (Dell 6850 and 1950), VMware GSX and later ESX along with Virtual Console was installed to gain experience with server virtualization.

During this timeframe, the Theater Battle Management Core Systems (TBMCS)-centric approach was redirected to an active directory infrastructure including Exchange, web applications, and Oracle. A TBMCS build was selected as it integrated those packages and includes BEA WebLogic, Oracle, SQL, and Web-Based Timeline Analysis System (WebTAS). Initially, DHCP provided private address schema for the hosts and a previously engineered IP address schema for the VMs and related infrastructure. This decision later caused problems.

To properly evaluate VMware and more closely emulate MNC-I/C6's environment, new equipment and a SAN was needed. To ensure evaluation relevance, MNC-I/C6 provided a summary of the current NIPRNet, SIPRNet, and CENTRIXS environment, along with equipment they were looking to purchase.

SCALE-I clients were rebuilt and after completing the electrical remapping of server environment rack bringing blade chassis online. To have a real prototype of the proposed solution in the field the necessary steps were taken to be able to accurately replicate the proposed hardware configuration from MNC-I/C6. The racks were prepared and servers loaded with TBMCS 1.1.4 Build 3 supplement 10.

The virtual environment was based on the new network environment baseline to emulate the WWF suite and gain a true 1:1 comparison on the effects of virtualization. While the focus SCALE was no longer TBMCS virtualization, the TBMCS suite of software provided the essential elements of a standard infrastructure. Supplement 3 and TBONE DB/Theater Battle Operations Net-centric Environment (TBONE) Global Data was virtualized.

A weekly telecom with key players held for coordination. Shortly thereafter, SCALE was briefed to ACC/A6N personnel. A meeting was coordinated with ACC/A6N to share the initial testing results.

A physical server was built for AD membership on the virtual domain to provide a static DNS function. DNS appears to not be a prime candidate for virtualization as ESX hosts use DNS services for cross-communication. Until delivery of final equipment and permanent licenses, 30-day trial licenses were used to gain experience with the product.

5.1.1.2 Match equipment to MNC-I/C6 install

In an effort to provide relevant information and ensure a more solid comparison basis, MNC-I/C6 equipment was used to order matching equipment for testing desired end state. Since the goal was to evaluate the functionality of various VMware features and not replicate an exact copy of MNC-I/C6's physical network, the decision was made to test with two vice three Dell 6950s.

5.1.2 Phase II

VMware, Dell, and GCIC (formerly C2ISRB) personnel successfully installed Windows Server 2003, 32-bit Operating System and VMware Virtual Server ESX 3.0.1 on host servers. Existing VMs were migrated from the legacy environment. When planning future installations, address the following:

1. Use a managed versus unmanaged switch
2. Ensure SAN power connectors match
3. Ensure fiber cables for HBAs and SAN match

5.1.2.1 Migration (V2V) to SAN; imported legacy virtual environment

The VMware representatives began migrating five virtual servers on the first day. Two servers completed migrating successfully while the other three timed out. Eventually, two virtual servers were migrated in four hours. Finally, server migration was alternated to balance the load.

Outstanding items:

- Activate VMware licenses
- Move the Virtual Center to a dedicated (non-virtualized server, i.e., 1950)
- Create a non-virtualized DNS server for VMware HA to work properly
- Install VM Converter on the servers
- Test HA after the DNS server is installed

SAN and related infrastructure were installed and migration began for virtual suite to new AMD Platforms. Private DHCP address schema for the host severely impacted performance and caused numerous SAN install issues. Infrastructure IP addresses were hard mapped by the software and not released from the DHCP pool. This created IP conflicts that later necessitated a complete rebuild of the ESX servers. A complete rebuild of the hosts was in order and IP schema was adjusted to match.

VMs were cloned back to the Intel hosts (6850s), but unable to return VMs to local storage. Note: If the virtual machine is to be left intact on its original storage location, migration is <u>not</u> the solution. In such cases, the VMs should be cloned onto the SAN and the local data storage left intact.

Migration of VMs located on local store deleted them from their original locations slated to be hot backups. HBAs were installed in the 6850s and sewn into the SAN fabric. This allowed complete cross communication within the virtual environment. VMs were cloned back to their original storage locations resulting in drastically reduced migration times.

An 1855 blade was dedicated to provide domain, active directory, and DNS services. A second 1855 was dedicated to become the Virtual Center and VMware infrastructure licensing server. Updated DNS entries and pointer information significantly improved performance. All four ESX servers (two AMD-based 6950 and an Intel-based 1950 and 6850) were re-built for a clean, solid environment and DNS resolution. (This was necessary to remove residual routing, naming and IP information.) The 6850s were still licensed via trial software. The new AMD based servers were licensed via a dedicated blade licensing server running Virtual Center.

A Virtual Center order error meant an older version of virtual center (VC) v1.0, incompatible with ESX 3.0.1 was shipped. Upon discovery, MNC-I/C6 personnel were immediately notified and revealed the same order error. Fortunately, VC software version was corrected before MNC-I/C6 purchase. The correct version of VC v2.0 was expedited.

All VMs were migrated to a single server's control while the infrastructure was rebuilt. The final VM management server could no longer communicate due to the updated IP schema. VMware support quickly reestablished cross communication.

Due to a dual homed configuration error, VMs were abandoned on the SAN and re-imported manually. This decision avoided reconfiguring freshly loaded machines to communicate and threaten a clean baseline. There was no loss of functionality or data. The final ESX host was reloaded and added to the IP schema.

Advanced Micro Devices (AMD) Host Machines were VMotion capable and tested time with positive results. Migrations seemed a bit slow and system performance was noted as sluggish. It was determined that multi processor VMs will not exist on ESX6950B and must be run on ESX6950A. VMware representatives responded and identified it as a licensing issue. Cycling the licensing process on the host corrected the issue immediately.

The Intel based hosts were not configured for VMotion due to local licensing as opposed to the license server and due to the differences in memory, processor capability, etc.

5.1.2.2 VMotion/HA/DRS: Software Deficiency Identification and Resolution

Note: Various actions in this section overlap on the timeline of what has already been presented.

While a successful worst case VMotion test was initially completed, some small but significant issues with licensing and configurations impacted the end result and/or timeliness to a stable system environment. The TBMCS environment was rebooted and the servers migrated during critical time to include startup, login, drive mapping, web service access and TBMCS-WebLogic application server startup. Results across the board at this time were successful with a single missed ping at the moment of machine transfer. Starting services (even notoriously greedy services such as the BEA WebLogic had no noticeable impact on the migration or the services). VMotion was very encouraging during this first phase of testing.

5.1.2.3 DNS/IP connectivity

A non-virtualized AD controller/DNS was needed to provide essential DNS services to the hosts when the Primary AD Controller/DNS (VM) are offline.

The VC was built on a 1855 blade. Maintaining a physical AD/DNS controller significantly improved overall performance and system stability. This permitted maintenance actions without having a VM running to provide Virtual Center and License server functions.

All four ESX servers were rebuilt for a clean install using lessons learned and DNS resolution.

5.1.2.4 Migration failures

Initial testing experienced difficulties when machines refused to migrate. Migrations would stall at 78% and time out after 15 minutes. At the 78% point, VMs would be rendered unresponsive and occasionally orphan on the SAN. A VMware escalation engineer was dedicated to isolating the root cause.

During troubleshooting, the cluster was reconfigured removing Host A entirely. After rebooting, Host A rejoined as a managed host. With DRS and HA disabled, VMs successfully migrated 10/10 to and from Host A and Host B. DRS and HA were re-enabled and the system was given time to stabilize. Additional isolation troubleshooting revealed a possible bug in the migration check-pointing. The highest priority was given to isolating and correcting this problem and was briefed to VMware senior management until resolution.

After working through multiple HA and migration failures, to include rebuilding every host from scratch, VMware technical support confirmed that unless a live gateway was used, isolation failover and HA would not function as designed. VMs use the gateway to maintain a sense of self. Without a live gateway, the DRS and HA settings had a nearly opposite effect. Since the system did not have a live gateway, a gateway IP was added to the Virtual Center box and the default gateway for all hosts was changed to the virtual center's primary IP address. This change instantly resolved HA, DRS, and migration issues. Once stabilized, an AMD resource pool was created with DRS and HA enabled. With the problem resolved, the system dynamically load balanced in short order.

5.1.2.5 Maintenance Mode

Early during the evaluation, activating Maintenance Mode on a load balanced system would usually succeed but subsequent requests would periodically fail. It appeared that a host returning from maintenance mode initialized and advertised to the HA process that it was ready for VMs but not accepting migrations. Bouncing the maintenance mode request was a short term work around. A patch was tested to verify fix actions. Isolation actions were lauded by VMware.

Note: Non-affinity rules for ESX 3.0.1 will adversely affect normal operations in a two host system. A temporary fix action is to disable DRS affinity/non affinity rules for a two host resource pool. This problem should not affect resource pools with three or more hosts.

Open consoles to VMs adversely affected migration via VMotion. This appears to have been a contributing factor to the earlier migration issues. Open consoles affect the memory map of the interface and interferes with the checkpoints utilized in VMotion. An open console can hang a migration for up to 15 minutes.

5.1.2.6 Licensing

Licensing is an item of particular interest as a small licensing error could conceivably impact an entire infrastructure if not planned for properly. This is especially true in a multi-processor environment. Multi-processor servers converted to virtual machines result in multi-processor VMs. Many operating systems require a complete system rebuild when altering number of CPUs.

Licensing features and flexibility on purchased licenses seems to be the largest limiting factor. Licensing limitations was one possible cause that prevented the dual homed server from migrating the virtual machines across and necessitated abandoning the VM's on the SAN to be recovered via a recognized/licensed box. The dual-homed server showed up twice in VC, once with each IP address. One was licensed but inaccessible, the other was not licensed and unable to be managed (disconnected).

During some of the extensive troubleshooting mentioned above, ESX HOST A had HA problems and would not configure for HA or release licenses. Host A was rebuilt and the licensing server was reinstalled to gain full licensing benefits. The HA root user folder was inaccessible and would not change states via a command line interface. Real world impact note: Since the remaining ESX hosts were available, impact on normal operations would be externally minimal.

The greatest challenge using VMware centered on licensing and enforcement mechanisms (Macrovision's LM Tools) and learning proper use. All other issues were successfully resolved, but licensing locked into fixed-frame architecture. To solve a simple directory access problem, a host had to be rebuilt, removed, and then reinstalled on the Virtual Center server. Repeated licensing and de-licensing servers was necessary to bring the other servers into the VC. After hosts were all attached, the appropriate servers were configured with single licensing and new servers with the license server.

Note: VC will not add a host (even a licensed one) without a complete set of licenses available to support all functions (i.e., if licenses are exhausted, no additional servers will be added to VC's control).

5.1.2.7 VM Cloning

After SAN fine-tuning, legacy VMs were cloned back to their original locations but attempts to return control of the VMs failed. Keep in mind, migration is ***not*** the answer if the original VM must be left intact. This lesson was learned the hard way when the original virtual environment was moved (not copied) from the legacy cluster to the SAN. If a hot-backup on local storage is needed, VMs should be cloned onto the SAN while retaining local data storage.

5.1.2.8 SAN Tuning

It was discovered that the SAN could be further optimized. After enabling Read and Write caching in a memory balanced fashion SAN response, console responsiveness, migration times, and failover times improved dramatically. Since VM implementation utilizes more SAN resources on the read side, 256 MB was allocated to each read and write cache. This exceeds the current practice of allotting 100 MB to read and the remainder to write caching.

Original VM migration from local storage to the SAN took several hours, was limited to two simultaneous actions, and was prone to failure. After tuning SAN settings, migration, cloning, and other times accessing VMs improved drastically.

IP/DNS issues combined with SAN connectivity and inaccurate configurations were the major factors contributing to this poor performance. Once the IP and SAN issues were corrected, cloning times were reduced to as little as 12 minutes to or from local storage. Eight systems were cloned simultaneously with little overall performance impact.

5.1.2.9 HBA Troubleshooting

Once HBAs were installed onto the Intel-based systems and the SAN setup process was completed, the HBAs functioned properly and caused no issues. Note: If rebuilding an ESX server, unplug HBAs from the system while reloading the software to eliminate an extreme risk of SAN data loss.

5.1.2.10 P2V using VM Converter

The initial attempt to convert a physical machine to a virtual machine was unsuccessful. This was not a VMware limitation but rather the team's misunderstanding of the process. The entire WWF suite was slated for rebuild/reload so the existing environment was virtualized as an operational test of VMConverter to preserve the 'as-is' environment for future events. All conversions went smoothly with minimal invasiveness and was up and running the same day. The complete WWF suite consisting of eight core and four supporting servers was completely was virtualized with the exception of Oracle server. Since the host servers are x86-based versus Itanium, The 64-bit Itanium-based Oracle server software and hardware environment disqualified it from being a viable virtualization target. The source machines were available to their host network during the process and there was minimal impact on the operational environment.

Most dedicated servers are already multi-processor and converting them to virtual machines results in multi-processor VMs. This makes perfect sense when considering most operating systems necessitate a complete re-install when modifying the number of CPUs. Conversion from a notebook (client machine) took 15-20 minutes for a 20 GB machine. Converting the WWF suite took 30-45 minutes per server running up to four conversions concurrently. Client storage ranged from 15 GB to 40 GB in size depending on their function. If converting from the same IP schema as the target, the host machine is available during the conversion process. If the IP has to be changed for communication purposes, the system would be unavailable during that time or DNS and related infrastructure has to be updated to point to the new temporary IP.

On occasion, VMConverter may not work the first time every time but all of the servers tested successfully within three tries. Coworkers familiar with the client software noticed a marked improvement in performance under light load. The team was unable to perform a true load test on the virtual environment beyond a few users. Load testing will be coordinated for future evaluation and increased scrutiny. Future goal is to expand operational evaluation during upcoming WWF test events.

5.1.3 Phase III

5.1.3.1 Distributed Resource Scheduler (DRS)

Normal non-affinity rules adversely affect two host system operations. The work around is to not have DRS affinity/non-affinity rules in a two host resource pool. This should not affect resource pools with three or more hosts. This feature worked properly and in a timely manner once the system was configured properly. Attempting to influence DRS actions via rules in a two host system had a negative effect.

- DRS rules prevent load balancing and affect migrations and Maintenance Mode operations when only two hosts are available.
- Non-affinity rules on a two host system prevent migration of systems even when administrator attempts to override.

- Having an open console to a VM can affect the speed and occasionally the success of the migration via VMotion.

5.1.3.2 HA

After DRS issues were resolved, HA was enabled but the Systems Management Server (SMS) server migration failed. When initiated manually, a general system error was generated. Continued troubleshooting steps with VMware resolved the issue completely.

5.2 Virtualization Notes

Before initiating the virtualization process, document both current and desired IP configuration. Ensure a proper backup of the legacy configuration with a command (such as **ipconfig /all >ipconfig.txt**). Use the backup as a reference for the new virtualized adapters. The converter initializes that function replacing the network adapter with a virtual adapter. The resulting VM only sees the Virtual AMD Network Interface Cards (NIC) and dumps the previous IP configuration. The conversion process is non-destructive and has no impact on the legacy server save a small application that was easily removed after the conversion process. This makes a cold box backup viable for any machines converted. Allocated memory on the VM was optimized to increase performance.

After conversion, features such as sound cards and USB peripherals are stripped automatically. Drivers for some network devices may require re-installation for an AMD VM network to function properly. This proved troubling on servers with Intel and Broadcom driver suites installed. The CD-ROM drive had to be added to systems not originally having optical drives. This permitted the installation of VMTools and other needed software. Additional Integrated Drive Electronics (IDE) devices like optical drives may have to be removed from the new VM and a virtual version created to allow this functionality as well. This must be done before a VMTools install can be successful as the VMTools installation process uses the virtual CD Drive to map to its ISO and installation files. It should be noted that the new environment may trigger activation on Original Equipment Manufacturer (OEM) installations of Microsoft software not using the Air Force volume licenses and associated keys. The virtual environment virtualizes the BIOS and hardware substructure triggering a Microsoft Out-of-Box Experience (MSOOBE) event in OEM and retail installs.

5.3 POC Tables

ORGANIZATION	FUNCTIONAL AREA	POINT OF CONTACT
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5.4 WWF and TBMCS Before / After

5.4.1 Equipment (Before / After)

	Before	After
1	2850/AD1	6950/ESX Host 1
2	7250/Oracle	6950/ESX Host 2
3	6850/WEEMC	7250/Oracle
4	6850/Web1	1855/AD/DNS
5	1855/Web2	1855/VC/VIC
6	1855/AD2	M70 Console
7	1855/SMS	
8	1855/Exch	
9	1855/Iris(Exch)	
10	1855/Jabber	
11	1855/COT/C2PC	
12	1855/DLARS	

Table 1: WWF and TBMCS Equipment Before and After

5.4.2 Rack Diagrams (Before / After)

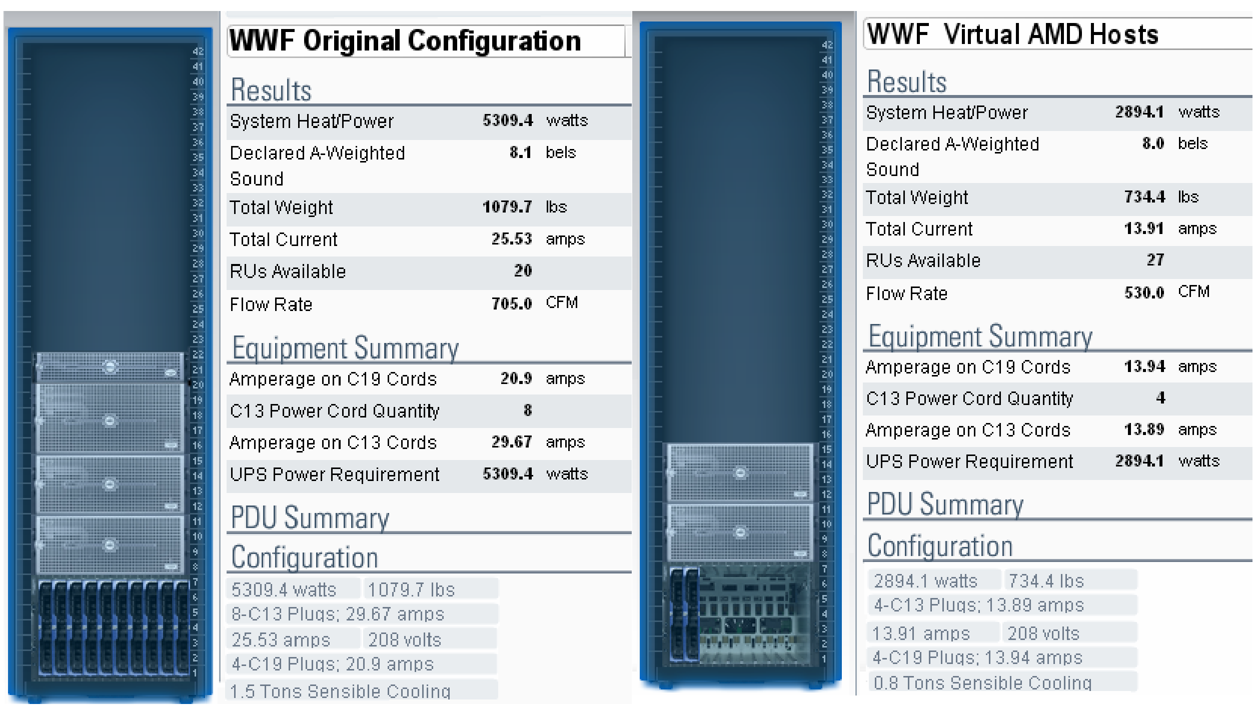

Figure 1: Before and After Rack Diagrams

* Generated by Dell Datacenter Capacity Planner v1.52:
http://www.dell.com/content/topics/topic.aspx/global/products/pedge/topics/en/config_calculator?c=us&l=en&s=gen

5.4.3 Virtual Center Console Management

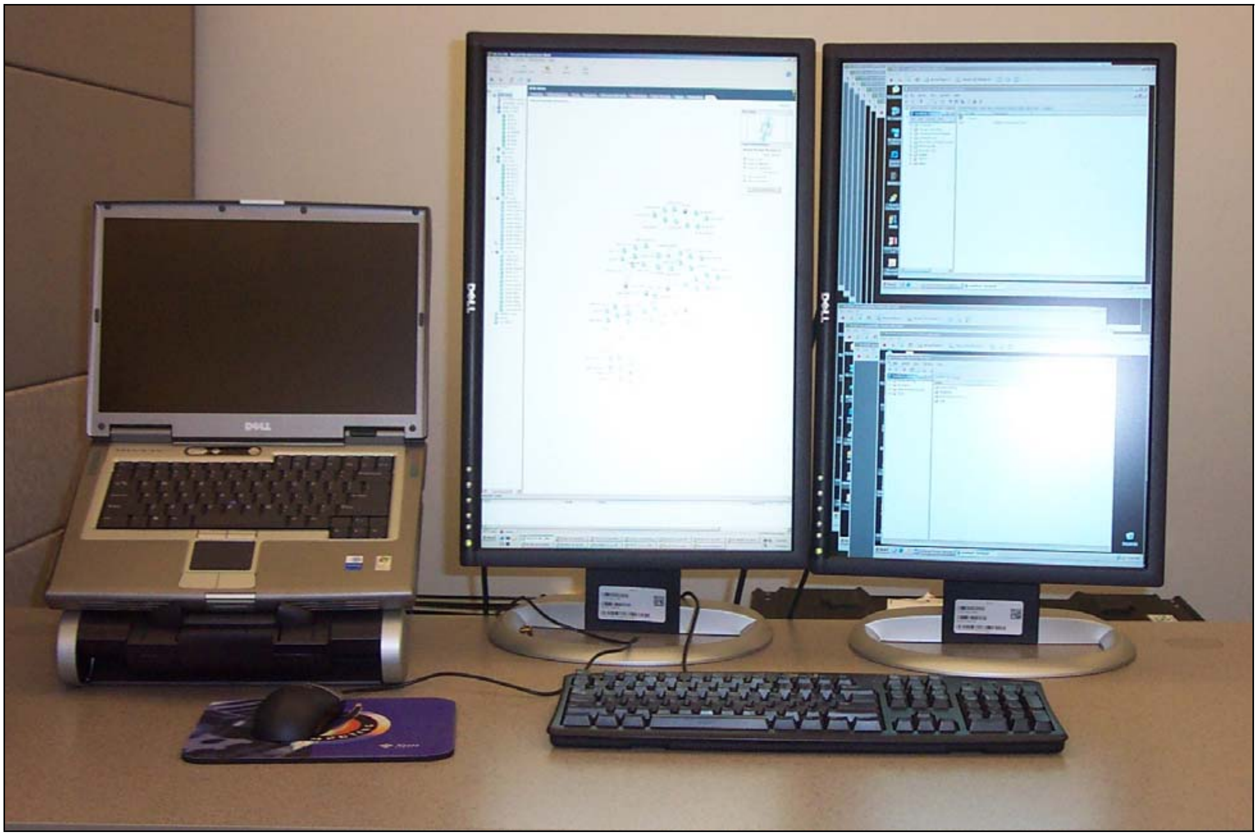

Figure 2: Console Management

5.5 MNC-I/C6 Before/After

	NIPR	SIPR*	CENTRIXS*
1	2650*	2850	2650
2	2650 – Exch/SMS	1750	2650
3	1850*	1750	2650
4	1750 – Cert Server	2650	2850
5	1750 – Cert Server	2850	1850
6	1750*	6850	1850
7	1750*	1850	1750
8	1750 – ELM, SQL, Spotlight	1750	1750
9	1750 – Exch, Spotlight, SQL	1750	1750
10	2850 – IA	1750	2850
11	1850 – IA	2850	1750
12	2850 – IA	1750	1650
13	2850 – IA	1750	1650
14	1750*	1750	2650
15	1750*	1750	
16	1750*	1750	
17	1850 – DC	1750	
18	1850 – DC	1750	
19	1750 – DC	1750	
20	1750 – DC	2650	
21	1750*	1750	
22	1750*		
23	2650*		

Table 2: MNC-I/C6 Equipment Before Virtualization

* NIPR, SIPR, CENTRIXS equipment breakdown unavailable

	NIPR	SIPR	CENTRIXS
1	6950 – load balanced	6950 – load balanced	6950 – load balanced
2	6950 – load balanced	6950 – load balanced	6950 – load balanced
3	6950 – load balanced	6950 – load balanced	6950 – load balanced

Table 3: MNC-I/C6 Equipment After Virtualization

5.6 NIPR Rack Diagrams

Figure 3: NIPR Rack Diagrams

5.7 SIPR Rack Diagrams

Figure 4: SIPR Rack Diagrams

5.8 CENTRIXS Rack Diagrams

Figure 5: CENTRIXS Rack Diagrams

5.9 Rack Comparison Diagram

Figure 6: Before / After Rack Comparison Diagram

5.10 Virtualization Cost Avoidance

NIPR HVAC/Power (before)			
HVAC		Power	Total
2.4	ton		
12000	btuh/ton		
28800	btuh		
0.0002928	kWhr/btu		
8.43	kWh	8.57	17.00
$ 0.055	$/kWh	$ 0.055	
$ 0.46	hr	$ 0.47	$ 0.94
$ 11.13	Cost/day	$ 11.31	$ 22.44
$ 77.92	Cost/week	$ 79.20	$ 157.11
$ 333.93	Cost/mo	$ 339.41	$ 673.34
$ 1,335.73	Cost/qtr	$ 1,357.65	$ 2,693.38
$ 4,062.85	Cost/yr	$ 4,129.51	$ 8,192.35

SIPR HVAC/Power (before)			
HVAC		Power	Total
2.2	ton		
12000	btuh/ton		
26400	btuh		
0.0002928	kWhr/btu		
7.73	kWh	7.98	15.71
$ 0.055	$/kWh	$ 0.06	
$ 0.43	hr	$ 0.44	$ 0.86
$ 10.20	Cost/day	$ 10.54	$ 20.74
$ 71.42	Cost/week	$ 73.77	$ 145.20
$ 306.10	Cost/mo	$ 316.17	$ 622.27
$ 1,224.42	Cost/qtr	$ 1,264.67	$ 2,489.08
$ 3,724.28	Cost/yr	$ 3,846.69	$ 7,570.97

CENTRIXS HVAC/Power (before)			
HVAC		Power	Total
1.5	ton		
12000	btuh/ton		
18000	btuh		
0.0002928	kWhr/btu		
5.27	kWh	5.27	10.54
$ 0.055	$/kWh	$ 0.055	
$ 0.29	hr	$ 0.29	$ 0.58
$ 6.96	Cost/day	$ 6.96	$ 13.92
$ 48.70	Cost/week	$ 48.71	$ 97.41
$ 208.71	Cost/mo	$ 208.77	$ 417.48
$ 834.83	Cost/qtr	$ 835.08	$ 1,669.92
$ 2,539.28	Cost/yr	$ 2,540.05	$ 5,079.33

NIPR HVAC/Power (after)			
HVAC		Power	Total
0.4	ton		
12000	btuh/ton		
4800	btuh		
0.0002928	kWhr/btu		
1.41	kWh	1.62	3.02
$ 0.055	$/kWh	$ 0.055	
$ 0.08	hr	$ 0.09	$ 0.17
$ 1.86	Cost/day	$ 2.13	$ 3.99
$ 12.99	Cost/week	$ 14.93	$ 27.92
$ 55.66	Cost/mo	$ 64.00	$ 119.66
$ 222.62	Cost/qtr	$ 256.01	$ 478.63
$ 677.14	Cost/yr	$ 778.69	$ 1,455.83

SIPR HVAC/Power (after)			
HVAC		Power	Total
0.4	ton		
12000	btuh/ton		
4800	btuh		
0.0002928	kWhr/btu		
1.41	kWh	1.62	3.02
$ 0.055	$/kWh	$ 0.055	
$ 0.08	hr	$ 0.09	$ 0.17
$ 1.86	Cost/day	$ 2.13	$ 3.99
$ 12.99	Cost/week	$ 14.93	$ 27.92
$ 55.66	Cost/mo	$ 64.00	$ 119.66
$ 222.62	Cost/qtr	$ 256.01	$ 478.63
$ 677.14	Cost/yr	$ 778.69	$ 1,455.83

CENTRIXS HVAC/Power (after)			
HVAC		Power	Total
0.4	ton		
12000	btuh/ton		
4800	btuh		
0.0002928	kWhr/btu		
1.41	kWh	1.62	3.02
$ 0.055	$/kWh	$ 0.055	
$ 0.08	hr	$ 0.09	$ 0.17
$ 1.86	Cost/day	$ 2.13	$ 3.99
$ 12.99	Cost/week	$ 14.93	$ 27.92
$ 55.66	Cost/mo	$ 64.00	$ 119.66
$ 222.62	Cost/qtr	$ 256.01	$ 478.63
$ 677.14	Cost/yr	$ 778.69	$ 1,455.83

NIPR HVAC/Power (savings)			
HVAC		Power	Total
2.0	ton		
12000	btuh/ton		
24000	btuh		
0.0002928	kWhr/btu		
7.03	kWh	6.95	13.98
$ 0.055	$/kWh	$ 0.055	
$ 0.39	hr	$ 0.38	$ 0.77
$ 9.28	Cost/day	$ 9.18	$ 18.46
$ 64.93	Cost/week	$ 64.26	$ 129.19
$ 278.28	Cost/mo	$ 275.41	$ 553.69
$ 1,113.11	Cost/qtr	$ 1,101.64	$ 2,214.75
$ 3,385.70	Cost/yr	$ 3,350.82	$ 6,736.53

SIPR HVAC/Power (savings)			
HVAC		Power	Total
1.8	ton		
12000	btuh/ton		
21600	btuh		
0.0002928	kWhr/btu		
6.32	kWh	6.37	12.69
$ 0.055	$/kWh	$ 0.055	
$ 0.35	hr	$ 0.35	$ 0.70
$ 8.35	Cost/day	$ 8.41	$ 16.75
$ 58.44	Cost/week	$ 58.84	$ 117.28
$ 250.45	Cost/mo	$ 252.16	$ 502.61
$ 1,001.80	Cost/qtr	$ 1,008.66	$ 2,010.46
$ 3,047.13	Cost/yr	$ 3,068.01	$ 6,115.14

CENTRIXS HVAC/Power (savings)			
HVAC		Power	Total
1.1	ton		
12000	btuh/ton		
13200	btuh		
0.0002928	kWhr/btu		
3.86	kWh	3.66	7.52
$ 0.055	$/kWh	$ 0.055	
$ 0.21	hr	$ 0.20	$ 0.41
$ 5.10	Cost/day	$ 4.83	$ 9.93
$ 35.71	Cost/week	$ 33.78	$ 69.49
$ 153.05	Cost/mo	$ 144.77	$ 297.82
$ 612.21	Cost/qtr	$ 579.08	$ 1,191.29
$ 1,862.14	Cost/yr	$ 1,761.36	$ 3,623.50

Combined HVAC/Power (before)			
HVAC		Power	Total
6.1	ton		
12000	btuh/ton		
73200	btuh		
0.0002928	kWhr/btu		
21.43	kWh	21.83	43.26
$ 0.055	$/kWh	$ 0.055	
$ 1.18	hr	$ 1.20	$ 2.38
$ 28.29	Cost/day	$ 28.81	$ 57.10
$ 198.04	Cost/week	$ 201.68	$ 399.72
$ 848.75	Cost/mo	$ 864.35	$ 1,713.09
$ 3,394.98	Cost/qtr	$ 3,457.40	$ 6,852.38
$ 10,326.40	Cost/yr	$ 10,516.25	$ 20,842.65

Combined HVAC/Power (after)			
HVAC		Power	Total
1.2	ton		
12000	btuh/ton		
14400	btuh		
0.0002928	kWhr/btu		
4.22	kWh	4.85	9.06
$ 0.055	$/kWh	$ 0.055	
$ 0.23	hr	$ 0.27	$ 0.50
$ 5.57	Cost/day	$ 6.40	$ 11.97
$ 38.96	Cost/week	$ 44.80	$ 83.76
$ 166.97	Cost/mo	$ 192.00	$ 358.97
$ 667.87	Cost/qtr	$ 768.02	$ 1,435.88
$ 2,031.42	Cost/yr	$ 2,336.06	$ 4,367.48

Combined HVAC/Power (savings)			
HVAC		Power	Total
4.9	ton		
12000	btuh/ton		
58800	btuh		
0.0002928	kWhr/btu		
17.22	kWh	16.98	34.20
$ 0.055	$/kWh	$ 0.055	
$ 0.95	hr	$ 0.93	$ 1.88
$ 22.73	Cost/day	$ 22.41	$ 45.14
$ 159.08	Cost/week	$ 156.88	$ 315.96
$ 681.78	Cost/mo	$ 672.34	$ 1,354.12
$ 2,727.12	Cost/qtr	$ 2,689.38	$ 5,416.49
$ 8,294.98	Cost/yr	$ 8,180.19	$ 16,475.17

5.11 Virtualization Comparison

Event Description	Physical Machine	Virtual Machine
Time to load Baseline	60 min	60 min
Downtime due to network connection failure	Until repaired	2
Downtime for PMI	15	0
Time to copy a machine[1]	45-90	15
Boot Time[2]	5	1-3
Upgrade Memory	15-30	5
Set up new server requirement[3]	Contract & Delivery	60
Shut Down Domain or group of 5-10 Servers	2 Min/server (Sequential)	2 Min (Simultaneous)
Start Domain or group of 5-10 Servers	5	3
Ambient Cabinet Temperature	87.8 ºF	71.6 ºF

Event Description	Virtualized Metrics Non-Optimized *	Optimized*
Migrate Virtual Machine between Data Stores	120-240[4]	10-15
Clone Virtual Machine	30-60[4]	5-15
VMotion Typical	1-2[5]	<1
Start Virtual Machine (boot)	3	<2
High Availability (failover/redundancy)	5-10	2

Event Description	Physical Metric	
Convert Physical Server to Virtual Machine (VMConverter)	15-60	
Rebuild ESX Host	30-45	

Note 1 Using Ghost to back-up and then restore a physical machine, VMWare Cloning for the virtual counterpart.

Note 2 Booting a physical ESX Host requires the same amount of time as the physical machine. Virtual boots are accelerated by the virtualized BIOS.

Note 3 Scenario is "I need a new server set up for this project." with no extra equipment on hand and no prior coordination.

Note 4 In a non-optimized environment, many functions are prone to failure. This item denotes moving from local storage to SAN storage or vice-versa.

Note 5 In a non-optimized environment, many functions are prone to failure. Failure to migrate does not mean a failure of the virtual machine, only a failure to relocate.

*** Non-optimized**: System as initially installed, no physical DNS or Virtual Center and no caching on the SAN. DHCP also created issues which severely impacted performance.
* **Optimized**: Balanced caching on the SAN, dedicated AD services, Virtual Center and static IP schema for infrastructure communication.

5.12 Acronyms

ACC/A6N	Air Combat Command, Network Systems Division, Langley AFB VA
AD	Active Directory
AFCA	Air Force Communications Agency
AFC2ISRC	Air Force Command and Control & Intelligence, Surveillance, and Reconnaissance Center, Langley AFB VA (renamed GCIC)
AFTC	Air Force Transformation Center
AIR	After-Initiative Report
AMD	Advanced Micro Devices; type of CPU
AOC	Air Operations Center
AOR	Area of Responsibility
C2ISRB	Command and Control and Intelligence, Reconnaissance Battlelab
CDE	Constellation Development Environment
CENTRIXS	Combined ENTerprise Regional Information eXchange System
CPU	Central Processing Unit
DB	Database
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DREN	Defense Research and Engineering Network
DRS	Distributed Resource Scheduler;
DoD	Department of Defense
FQDN	Fully Qualified Domain Name
GB	Gigabyte
GCIC	Global Cyberspace Integration Center (formerly known as AFC2ISRC)
HA	High Availability (failover)
HBA	Host Bus Adapter
HVAC	Heating, Ventilation, and Air Conditioning
IDE	Integrated Drive Electronics
IP	Internet Protocol
IT	Information Technology
KVM	Keyboard, Video, Mouse
LIMFAC	Limiting Factor
MB	Megabyte
MNC-I/C6	Multi-National Corps Iraq C6, Camp Victory, Baghdad, Iraq
MSOOBE	Microsoft Out of Box Experience (anti-piracy mechanism for WinXP and Server 2003)
NCC	Network Control Center
NIC	Network Interface Card
NIPRNet	Non-Secure Internet Protocol Router Network
NOSC	Network Operations and Security Center

OEM	Original Equipment Manufacturer
P2V	Physical to virtual (precursor to VMConverter)
PMI	Preventive Maintenance Inspection
PPL	Preferred Products List
RAM	Random Access Memory
SAF/XCI	Secretary of the Air Force Warfighting Integration and Chief Information Officer; Information, Services and Integration Directorate
SAN	Storage Area Network
SCALE	Server Consolidation for Advanced Leveraging of Equipment
SIPRNet	Secure Internet Protocol Router Network
SMS	Systems Management Server
SQL	Structured Query Language
TB	Terabyte
TBMCS	Theater Battle Management Core Systems
TBONE	Theater Battle Operations Net-centric Environment
V2V	Virtual to virtual
VC	Virtual Center
VIC	Virtual Infrastructure Client
VM	Virtual Machine
VMConverter	Formerly P2V
WebTAS	Web-Based Timeline Analysis System
WWF	Warfighter to Warfighter Forwarder