Designing and Building a classroom computer laboratory For hands on and theoretical learning in an IT program.

A Capstone Report submitted to the
Science and Technology Division of
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In Partial Fulfillment of
the requirements for the degree of
Bachelor of Applied Technology in
Network Engineering

by

John Q. Public

Bill Gates, Ph.D., Committee Chair
Isaac Newton, Ph.D.
Stephan Hawking, Ph.D

West Virginia University at Parkersburg

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Abstract

In order to accommodate the growth in the CIT and BAT programs, enhance the learning environment available to students in these programs, and protect the rest of the WVU-Parkersburg campus network, a complete overhaul of the existing classrooms used for these programs was undertaken. The first component of this involved converting two environmental science classrooms to state of the art computer labs. These two classrooms replaced two smaller lecture rooms which had only an ad-hoc network and limited resources. They also greatly improved safety and access to the network hardware. They needed new electrical and network cabling, computer desks, and new computers with all appropriate software installed and configured, as well as an instructor station.

The next major component of the overhaul involved re-wiring three other classroom networks, and connecting them back to the same central point as the two new computer labs, then connecting the CIT/BAT classroom network to the rest of the WVU-Parkersburg campus. This project also provided a unique opportunity to showcase the various technologies and strategies taught in the classroom, in a real world environment. In order to provide the autonomy and security desired, a new network server and security system was installed at the central access point. These servers provide necessary infrastructure services to student and faculty computers.

The final stage of the project involved configuring, installing, securing, and maintaining student workstations in each lab.

The specific objectives of this project were to:

A) Design and build two new computer classrooms, including all electrical wiring, physically installing all computers, and building a new physical network connecting these rooms to a central access point and to a new central equipment room.

B) Re-wire three existing computer classroom networks

C) Connect the three existing classrooms and two new classrooms back to a central access point (server cabinet/closet), creating an extended star topology

D) Secure access to and from the network segment and the rest of the school

E) Configure servers and workstations for use by students, faculty, and staff

Acknowledgements

i. Special thanks should go to the Cisco Area Training Academy (CATC) at the New Hampshire Technical Institute, whose Cisco Academy laboratory was the basis for the cabling design used in the CIT Cisco Academy classrooms

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1 – Introduction

1.1 Project Introduction and Background

The Computer and Information Technology (CIT) Associates of Applied Science (A.A.S.) degree is a relatively new two year degree housed at the Caperton Center for Applied Technology (CCAT) at WVU-Parkersburg. The CIT program teaches the theory and application of computer, system, and network engineering in both an A.A.S. two year program, as well as the even newer Bachelor's of Applied Technology (BAT) four year program. These programs emphasize both the concept and application of current, state of the art and state of the industry technology, including: computer hardware, Microsoft Windows XP and Server 2003 operating systems, and the Linux operating system, as well as network theory and implementation through the Cisco Systems ® Networking Academy program, which extensively covers networking with routers, switches, and hardware firewalls.

The CCAT was built on the WVU-Parkersburg campus in the late 1990's to house several new associate degree programs and a joint high-school dual credit program. Approximately half of the building is under the direction of Wood County schools, and half of the building is under the direction of WVU-Parkersburg. Each of these programs was created as a result of a multidisciplinary survey of area businesses conducted in the mid/late 1990's to discover future areas of growth in the local employment market, one of which is the CIT A.A.S. program.

Once each of these potential growth areas were identified, WVU-P created and updated several associates' degree programs in order to better meet the needs of the local community. When the United States economy went into a recession in early 2000, the employment market of the region took a drastic turn for the worse, and many of the potential areas of growth never materialized. As a result, several of the programs housed in the CCAT were canceled in 2003. Other programs, such as the CIT A.A.S. degree and BAT, grew more than expected.

1.2 Overview of the project

In order to accommodate the growth in the CIT and BAT programs, enhance the learning environment available to students in these programs, and protect the rest of the WVU-Parkersburg campus network, a complete overhaul of the existing classrooms used for these programs was undertaken.

The first component of this involved converting two classrooms originally used to house the Environmental Science A.A.S. program, which was canceled due to low enrollment in 2003, to state of the art computer labs in order to accommodate the diverse technological and educational needs of these unique programs. These two classrooms replaced two smaller lecture rooms, which had only an ad-hoc network and limited physical resources for hands-on learning. They also greatly improved safety and access to the network hardware such as routers, switches, and firewalls used to teach by providing a dedicated equipment room in between, where students can access all available hardware. They needed new electrical and network cabling, computer desks, and new computers with all appropriate software installed and configured, as well as an instructor station with educational tools such as an overhead projector, whiteboards, and a classroom network capable printer.

The next major component of the overhaul involved re-wiring three other classroom networks already assigned to the CIT and BAT program, and connecting them back to the same central point as the two new computer labs. Once this was accomplished, then a secure central access point was also configured between the CIT/BAT classroom network and the rest of the WVU-Parkersburg campus. At the time, there were several concerns that the skills being taught to the IT students in these programs could be used to by a disgruntled student to wreak havoc on the main campus network. In addition, the IT faculty had expressed a desire to separate the campus network in order to minimize security threats such as viruses which often propagate from the main campus, and to provide a greater degree of autonomy which many deem necessary for such a program. This project also provided a unique opportunity to showcase the various technologies and strategies taught in the classroom, in a real world environment.

In order to provide the autonomy and security desired, a new network server and security system was installed at the central access point. This new network server system consists of two new Windows Servers, a central switch which all five classrooms will connect to, and a router with enhanced security configuration to route network traffic to and from the new CIT/BAT classroom network. These servers provide services to student and faculty computers such as: Authentication, file and print sharing, domain name services (DNS), automatic IP addressing through a DHCP server, automatic client installation through the Windows Remote Installer Service (RIS). In addition, security configuration has been highly automated through tools such as Windows Group Policy, Windows Software Update Services (WSUS), and the Microsoft Baseline Security Analyzer (MBSA).

The final stage of the project involved purchasing where necessary, configuring, installing, securing, and maintaining student workstations in each lab. These workstations connect to the new servers and have all software installed via RIS, and receive configuration and security settings automatically. The ultimate goal was to have each room offer the best possible opportunity for all students to maximize their hands-on learning in each topic through real world experience, while maintaining security and functionality for other classes, other students, and the rest of the campus.

2 – Triple Constraints

When any project is undertaken, priority must be given to the areas that are most important to the project's success. These drivers include the performance of the completed system, the resources used to complete the project, and the time that it takes to complete the project. Because these drivers compete against each other for primacy in a project, they are sometimes referred to as constraints in project management nomenclature.

The three major constraint criteria imposed upon the project were as follows:

2.1 Performance

The performance metric of the project involved accommodating the growth in the CIT and BAT program, and improving the existing system by enhancing the capability of students and faculty members to maximize their hands-on learning in each topic through real world experience, while maintaining security and functionality for other classes, other students, and the rest of the campus. Performance was the primary driver, because the entire purpose of the project was to expand the CIT and BAT program in order to offer more and better educational opportunities for students.

For this project, there were two major performance issues to consider. First, if the project does not increase the capacity of the program to handle larger enrollment, then the project would be a compromise or a failure (See Figure 2.1). In addition, if the new classroom environment didn't offer better student computer access, enhanced hands-on capability, and improved security for the program and the campus network, then the project would be a compromise or a failure (See Figure 2.2).

Figure 2.1 Accommodate Growth constraint

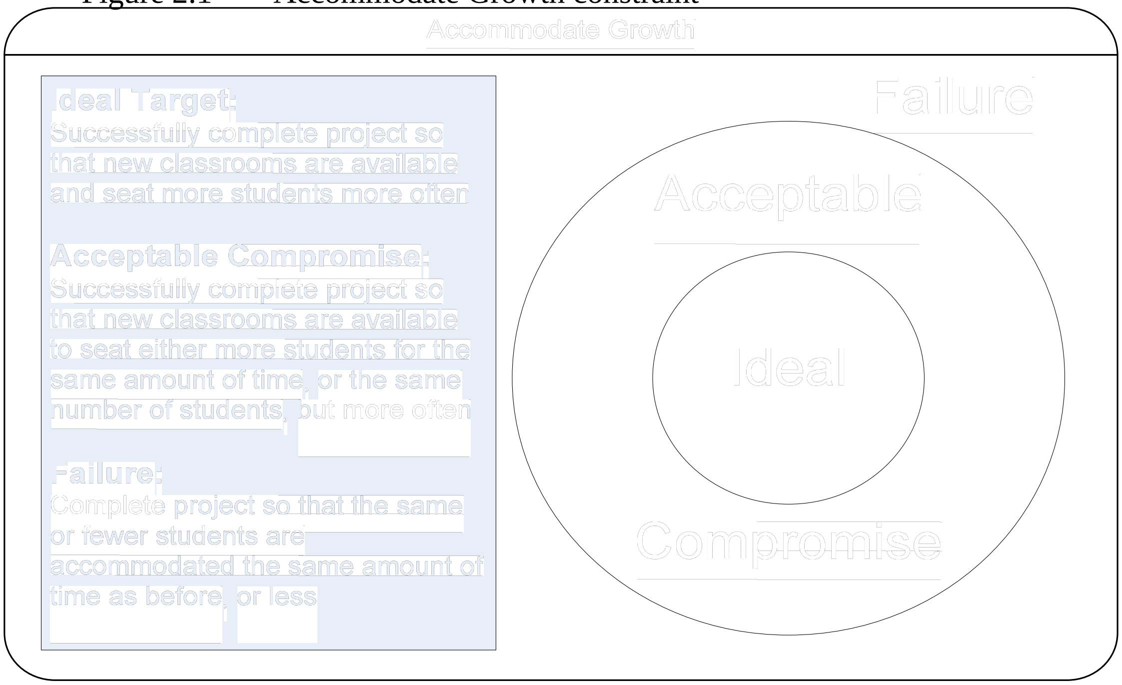
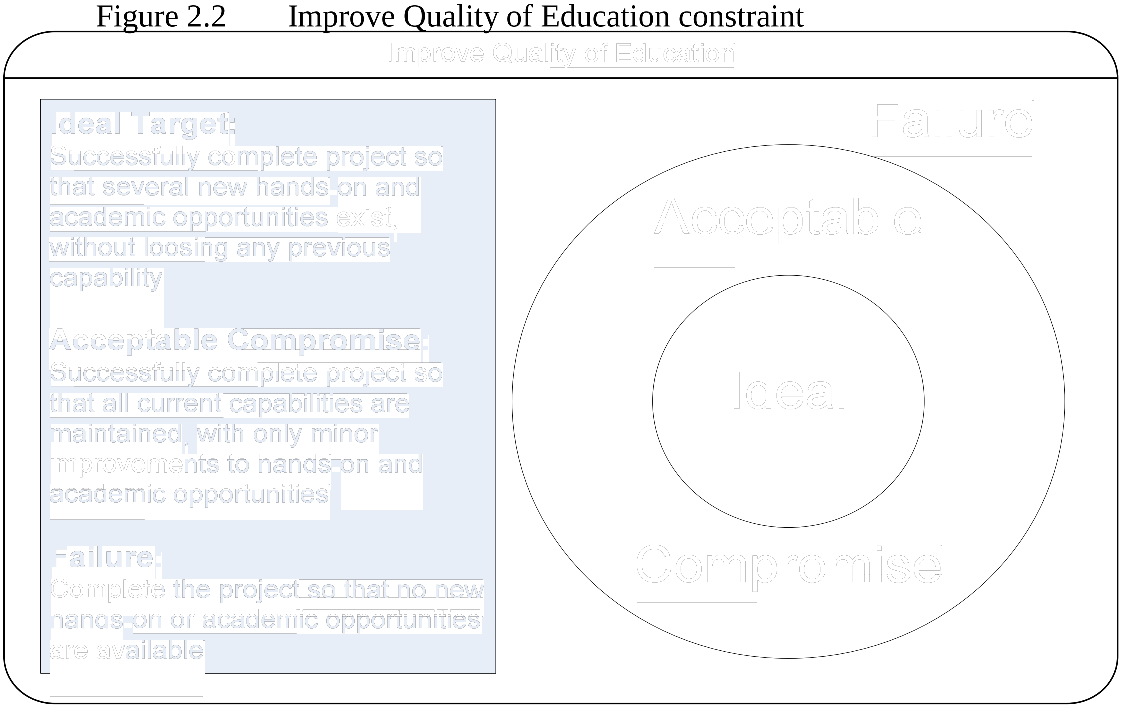


Figure 2.2 Improve Quality of Education constraint



2.2 Resources

The resources metric of this project included materials, tools, money, and manpower. Resources were the middle driver for this project. The faculty and administration both agreed that this project had to be undertaken in order to accommodate the growth and provide necessary improvements to the program.

For this project, there were several key resources to consider. First, the materials necessary to complete the project (See Figure 2.3); this included electrical and network cabling, terminations, computer and network hardware, desks and chairs, equipment cabinets and racks, uninterruptible power supplies (UPS), as well as software. Next, the tools necessary to complete the project, which included basics such as ladders, drills, screwdrivers, hammers, etc., as well as more specialized tools such as network terminators and testers (See Figure 2.4). In addition, money had to be available to purchase all necessary materials and pay for all the labor (See Figure 2.5). Finally, manpower is required to carry out each task of the project (See Figure 2.6). The challenge for this project involved accommodating the highly specialized skills and abilities required to do most of the tasks.

Figure 2.3 Materials constraint

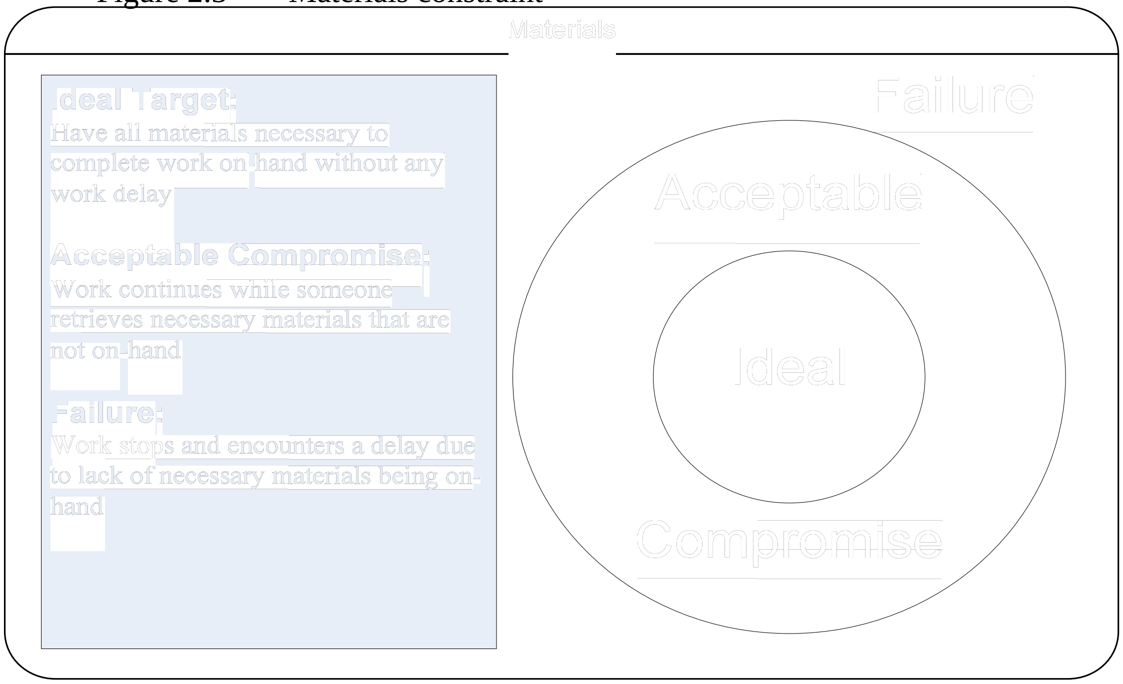


Figure 2.4 Tools Constraint

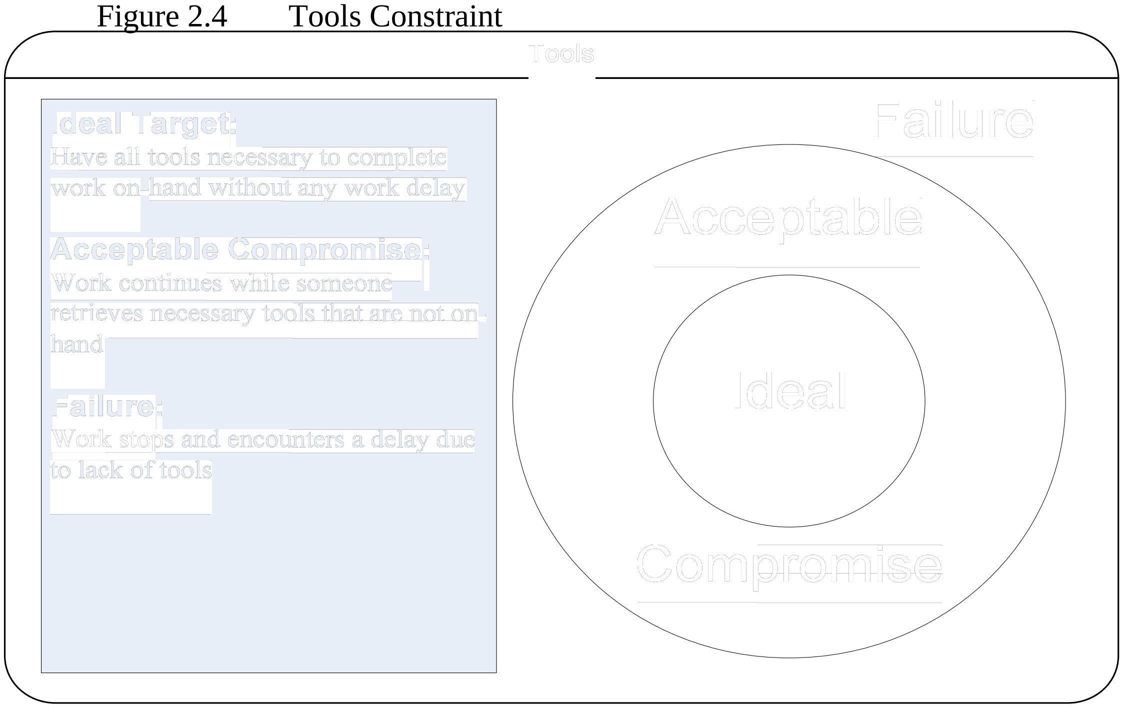


Figure 2.5 Money constraint

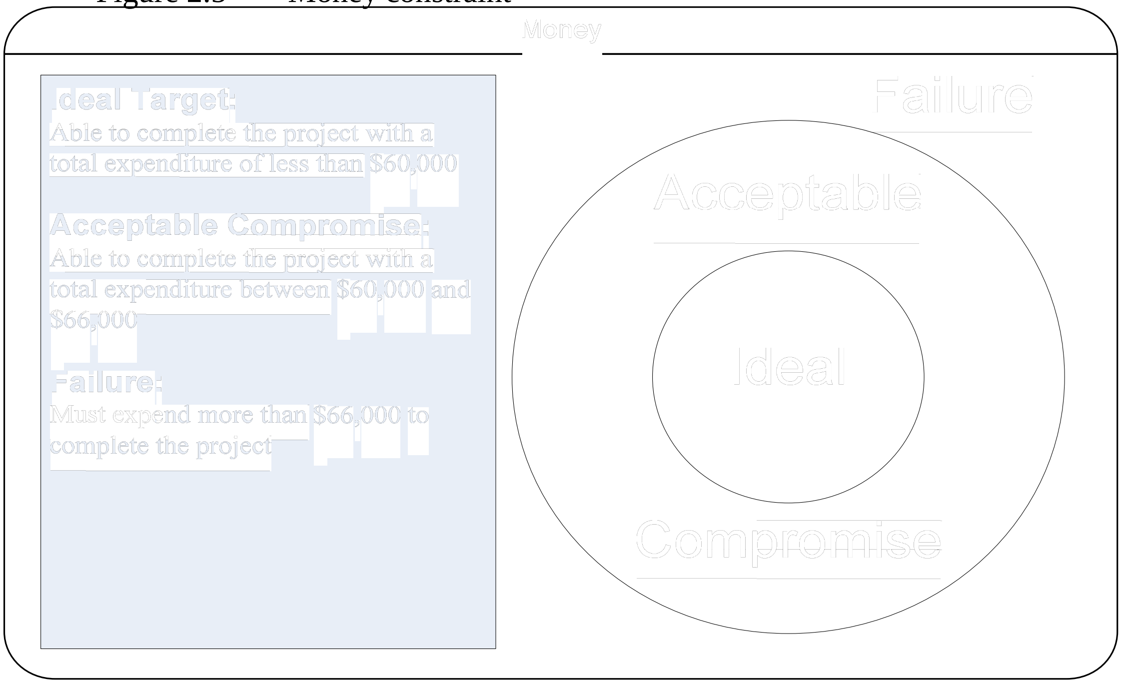
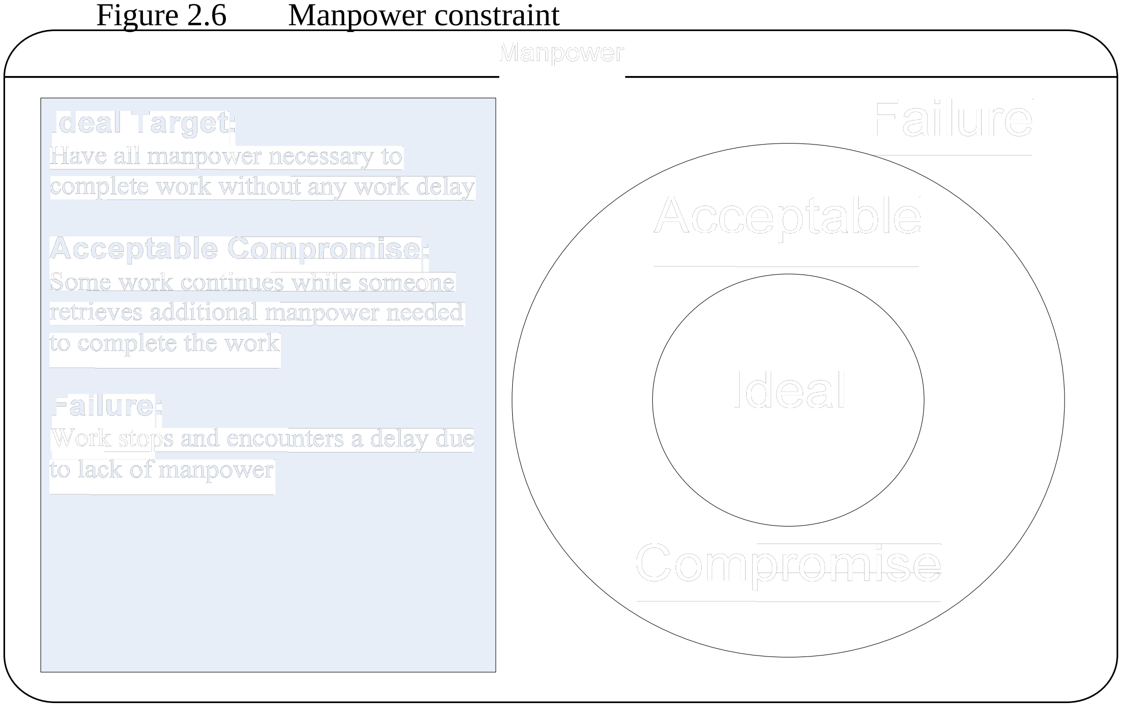


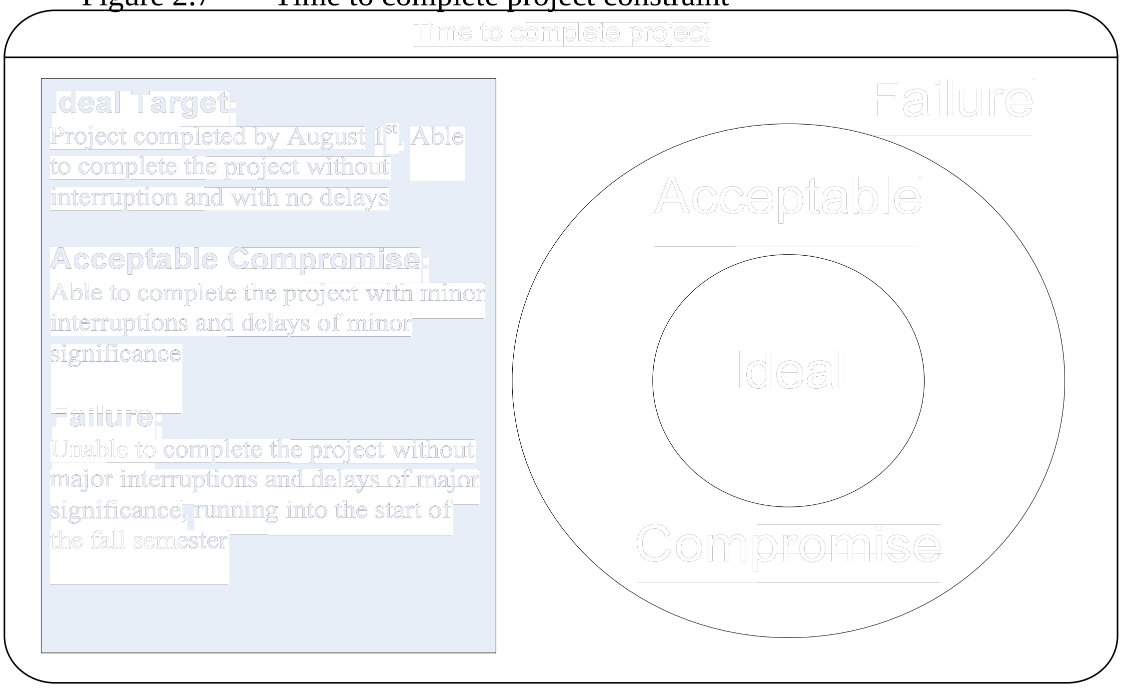
Figure 2.6 Manpower constraint



2.3 Time

The time metric for this project is the total duration required to complete the work (See Figure 2.7). Time was the weak driver for the project. The duration of the project was the weak driver because in order to accommodate the growth in the program, new classrooms must be set up, and in order to improve the quality of the program, better tools and a better learning environment should be set up, regardless of how long it took to do it (to some degree).

Figure 2.7 Time to complete project constraint



3 – Project deliverables, scope, and standards

3.1 Overview

The deliverables for the project involve wiring the new classrooms for electrical and network cabling, and re-wiring the three existing classrooms. Each classroom also needed the instructor station wired for access to a keyboard/video/mouse (KVM) switch, the overhead projector, and extra connections for instructor laptops. In addition to each of these, a central server closet was necessary, to connect each of the classrooms back to and to control and secure access to the rest of the campus and the Internet. Once the physical network was completed, then the student workstations needed a new install image of a standard configuration including the operating system (Windows XP) and a wide variety of software for use in various classes.

The scope of the project was limited to the five classrooms assigned to the CIT and BAT programs, and the central equipment room in between the two new classrooms. Since this project was undertaken at a state institution, several processes and procedures already exist and are required by institutional policy or by law for many of the key tasks, such as purchasing materials and equipment or hiring personnel. Resources included personnel from the WVU-Parkersburg faculty and staff, as well as student workers to manage and execute the project.

3.2 Wiring the Classrooms

3.2.1 Overview

Wiring the two new classrooms was a two step process. The first step involved running electricity to computer desks where there was previously no need for electricity. The WVU-Parkersburg maintenance department has traditionally used power poles that connect into a drop ceiling to provide new electrical access. These power poles also have a second channel built into them to allow computer network cabling, which allow both electricity and network connections in one location.

The second step involved installing a new physical network for the student workstations to access the campus network and Cisco Academy networking equipment. In order to accommodate this, a new system of surface mount boxes at each workstation, with four RJ-45 network ports was installed. Each of these connected a workstation via Category 5e cable to a corresponding surface mount box with four RJ-45 ports in the central equipment room. This system allows students to have up to four simultaneous devices connected to each workstation for configuration and testing.

Cabling the instructor station involved several unique considerations. Several instructors have laptops, and want to use their laptops with the overhead projector when teaching. The classroom overhead projector uses a VGA splitter to connect the instructor workstation to both the projector and the computer monitor. To make things as simple as possible, a KVM switch will allow instructors to cable their laptop directly to the KVM switch and press a button to use the instructor workstation keyboard, mouse, and monitor directly with the overhead projector, while also leaving everything connected to the instructor workstation.

In addition, the classroom printer is located at the instructor station, and requires an additional network connection, along with an extra network connection for the instructor laptops. To accommodate these extra network connections, an eight port switch was also added at the instructor workstation to connect these extra devices into the campus network. Given the increasing popularity of USB flash drives and other USB peripherals, a USB capable KVM switch with a built-in USB hub was chosen.

Wiring the remaining three classrooms involved installing a small cabinet or wall mounted rack in the rooms. In the cabinet, a local patch panel was installed to terminate network cabling, and a local network switch was installed. Once this new switch was installed, then the horizontal network cabling had to be re-terminated at the wall mounted cabinet on the new patch panel, and patch cables from the patch panel into the switch were purchased. A connection from the new room cabinet to the central server cabinet was also be made. Once terminated at the server cabinet, all five classrooms connect to a central switch, which then can access the campus network and the Internet through a secure router.

3.2.2 Electricity

All electrical work followed code as established by law. The first step to installing new electrical outlets involved adding up the amount of service needed. For the two classrooms, the electrical service had to power approximately twenty-five computers each, as well as an overhead projector and a laser printer each. In the central equipment room, several routers and switches, as well as all equipment in the central server cabinet run off of the same service. In addition, the central equipment room was chosen as the ideal location for the central server cabinet. The server cabinet houses three servers, two switches, and one router, as well as four uninterruptible power supplies (UPS'). Once the electrical load was calculated, new circuit breakers were installed at the service panel, and wire supporting the load ran to the location of each of the power poles in the two classrooms and the central equipment room.

Computer stations receive electrical service through power poles running to each island of workstations (See Figure 3.1). Each power pole is equipped with four outlets, which is not enough to serve the four or eight workstations at each location. At each island of four computers, the power pole runs to the center of the tables, while at the row of eight computers in the center of the classroom the power pole comes down between the instructor station and student station on the left. In order to accommodate the number of power outlets required, surge protectors were mounted under the computer desks to provide enough outlets for all attached devices.

The central equipment room also had electrical service added to support the Cisco Academy networking equipment. The new service runs from the power panel through the ceiling to a section of conduit. This conduit runs down the wall on a surface mount to a wall raceway with seven new outlets installed. In order to provide this much new electrical service, outlets in other locations such as the environmental science lab tables, which are no longer needed, were disconnected in order to avoid upgrading the service to the building.

The central equipment room required power to six new outlets. This runs to one of several power line conditioners installed on the equipment racks in order to protect against “dirty power.” Each rack of equipment is laid out in a specific pattern of three routers and three switches in order to accommodate the Cisco Academy labs, which are all written around a three router/three switch topology to promote teamwork. These six devices are plugged into a rack mount power strip to further consolidate power cables and protect against surges. There are three racks of equipment with three of these bundles, and two other racks with two bundles of equipment. In addition to the routers and

Figure 3.1 Diagram of the two new classrooms (Drawing Not To Scale)

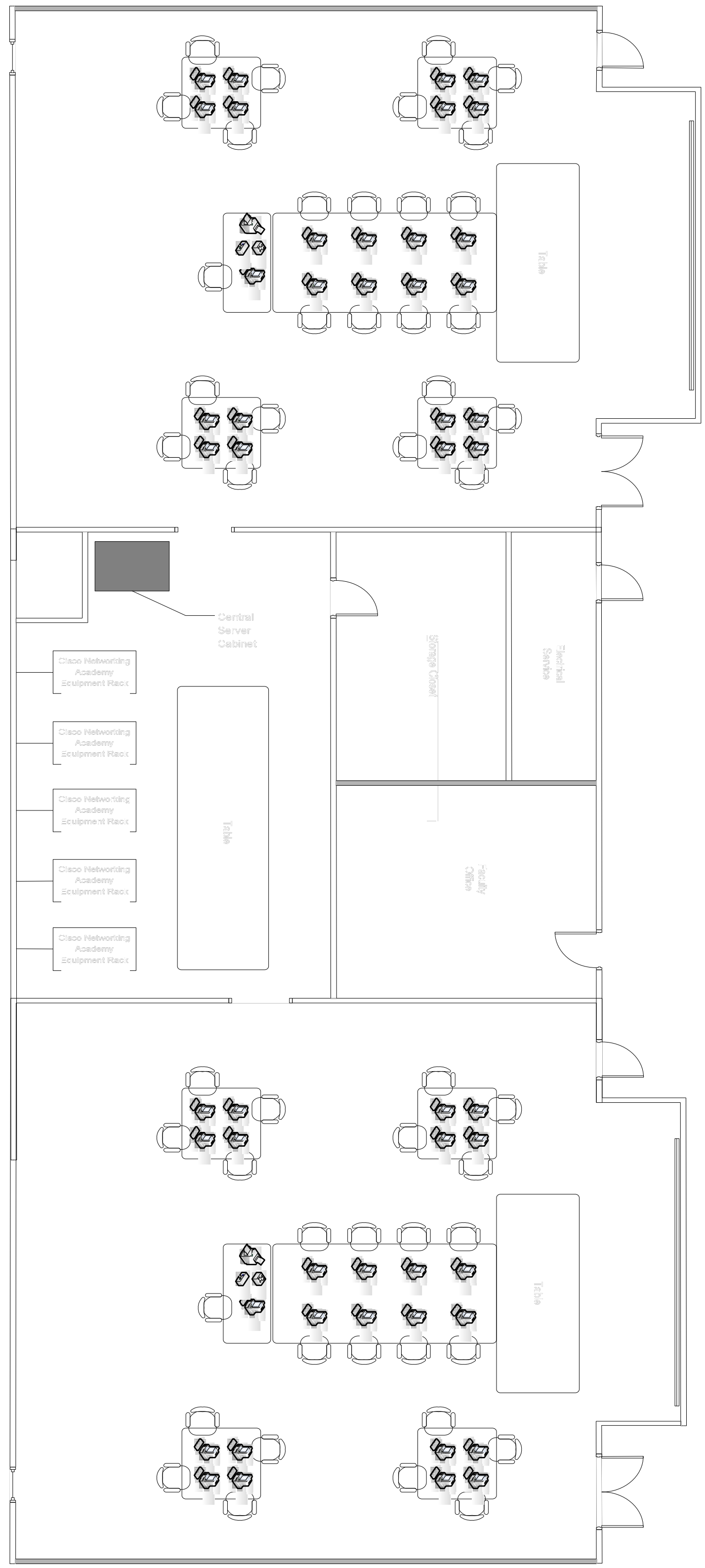
C221
24 Student Workstations

1 Instructor Station

C219
Central Server Cabinet
Network Connections to
C119, C123, and C127
Network Connection to
WVU-Parkersburg Campus
5 Cisco Networking
Academy Equipment Racks

C217
24 Student Workstations

1 Instructor Station



switches, there are also four AdTran Atlas 550 WAN emulators, which provide Frame-Relay, ISDN PRI and BRI service, and analog telephone service, to simulate various Wide Area Network technologies used by the IT and telecommunications industry.

The server cabinet only needed a single outlet to power the cabinet's internal power strip. From the internal power strip, electricity runs to four UPS'. Each of the three servers has a redundant power supply, which is plugged into two different UPS' for redundancy. A fourth UPS will provide uninterruptible power to the two switches and the router. These serve two purposes. The first is to protect the servers, router, and switches from "dirty power," and the second is to allow these critical computers to shut down cleanly if electrical service is ever interrupted.

3.2.3 Network Cabling

In order to facilitate access to all of the Cisco Networking Academy equipment, the new network design called for cabling each of the two new classrooms with a new computer network that allows for four RJ-45 ports at each workstation. Since Cisco routers, switches, and firewalls all use a standard RJ-45 connection to access their console port for configuration, the same connection can provide either a configuration or network capability. These four ports at each workstation are then terminated in the middle room, where all of the lab equipment is located. Each block of four ports is labeled at the student workstation and in the middle equipment room, and each port in the block is color coded, with red, white, blue, and grey. These blocks essentially act like extension cords, allowing easy access to the equipment without having to run cables across the floor or across desks where they can pose a safety hazard. By designing the network this way, one class can easily use all of the available equipment if there is no class in the other room, or if the class in the other room is lecturing instead of doing labs.

To provide network and Internet access to student workstations, a separate patch cable will then run from each block in the middle equipment room to the central server cabinet. If a student wants to use all four ports for lab equipment, they only need to unplug the patch cable from the port in the equipment room going to the central server cabinet. When they are done, they only need to plug the patch cable back into the correct port on the block to restore network and Internet access. In contrast, a student can also configure up to three devices at the same time, and keep their Internet connection for research.

To achieve this new design, the first thing necessary is to set up the central equipment room. In planning discussions with the maintenance department personnel, a large surface mounted raceway was recommended, running from the drop ceiling down to about shoulder height, then running horizontally across the wall behind the racks of lab equipment. Between the two classrooms, there are approximately fifty workstations, each with four cable drops, totaling two hundred cables. The surface raceway had to be large enough to handle this volume. In order to facilitate fifty blocks, two rows of the surface mounted raceway were needed. Each block from a workstation was terminated at a four-port faceplate mounted directly on this horizontal raceway.

In order to install the cable, several steps had to be taken. First, to purchase the correct amount of cable, the distance from each workstation along the path of the cable to the termination in the central equipment room was measured, and then multiplied by four to account for the four drops at each computer. Some extra was added at each station for slack. Next, the cable was ordered in the four colors being used, and four hundred RJ-45 jacks were also ordered in the four colors, along with one hundred faceplates, and fifty surface mount boxes. A few extra of each was ordered in case some were damaged or broken during installation so work would not be interrupted.

Once the materials were purchased, the real work began. The best way to approach a cabling project like this is to have four boxes of cable, one of each color, at one side of the network, and bundle all four together with tape, and label it. Then, the cable was pulled from the workstation location to the central equipment room where it will later be terminated in the horizontal raceway. Once the cable has been pulled and some slack added, the originating side was cut and taped together with a label for easy documentation. Once all the cable runs were made, then two people worked together to terminate the cable with RJ-45 connections at the workstations and in the central equipment room by terminating the same color on the same bundle at the same time, and testing it as they went. After all cables were terminated and tested, the ports were mounted on a faceplate, and the faceplate labeled on both ends. At the workstations, this was installed on a surface mount box, and then the box mounted to the desk, while in the central equipment room this was mounted to the horizontal raceway.

In order to complete the network connectivity for each workstation, a cable tray was installed above the horizontal raceway, and a patch cable was ran from each block along the horizontal raceway to the central server cabinet for student workstation access. The next step involved terminating these patch cables and testing them. By doing this, students are able to use all four ports for equipment connections, or they can use three ports for equipment connections and leave the fourth connected to this patch cable and have Internet access.

In order to complete this design, the other three classrooms also had to connect back to the central server cabinet in order to centralize connectivity. The most effective way to facilitate this was with an extended star topology, where each room connects to a central switch of its own, and then that switch connects back with a single cable run to the central server cabinet. By choosing this design, if a classroom would ever be assigned to another program in the future, it could easily be removed from the CIT classroom network by moving this one cable drop, instead of re-routing each workstation's cable drop. Also, the cost of cabling was significantly less, since cabling from each workstation only runs to the equipment rack in the room. Another benefit of this design for teachers is the ability to disconnect the room from the rest of the campus network and from the Internet by simply unplugging the cable connecting the room's switch to the central server cabinet's switch, which can be useful during exams or if students are browsing the Internet instead of paying attention.

Two of the three remaining rooms, C119 and C123, already had their workstations wired into a wall mount rack in each room. In room C119 the rack is approximately ten feet off of the floor, requiring a ladder to access it, and that room is only unlocked during class time. In contrast, the wall mounted rack in C123 is installed in a closet with a lockable door to provide physical security. Both room networks use an RJ-45 patch panel, and connect to a Cisco 2950 24 port switch. The only thing necessary to connect these two rooms into the new network topology was to run a new vertical cross connect cable from each room to the central server cabinet, thus making an extended star topology.

The one remaining room, C127, had each workstation wired separately to the building's main wiring closet on the second floor of the CCAT. In order to connect this room to the new network, a new wall mounted cabinet was purchased and installed, and each network cable drop was re-routed into this new cabinet and terminated on a patch panel. In order to save money and time, instead of tearing out the existing wiring, the new design left the current cabling in place at each wall jack, and re-routed the cable to the new cabinet and terminated on a patch panel. The new cabinet connects the workstations together with a Cisco 2950T 24 port switch. The 2950 T model was chosen because in addition to the twenty-four Fast-Ethernet (100 MBps) ports, it also includes two Gigabit-Ethernet (1000 MBps) ports. This class room has twenty-four student workstations, as well as an instructor station, and a connection from the room back to the central server cabinet. The twenty-four Fast-Ethernet ports can connect the student workstations, while the two Gigabit ports connect to the instructor station, and back to the central server cabinet.

3.3 Server Cabinet

One of the most important components of the new network design is the new central server cabinet. This is the center of the extended star topology, and also where the servers and the router for the new network are located. The server cabinet has a 48 port patch panel to terminate the student workstation connections running from the horizontal raceway into the server cabinet. Small patch cables connect the patch panel terminations to a new Cisco 2950 T 48 port switch. This switch also includes forty-eight

Fast-Ethernet ports, which connect the student workstations into the network, as well as two Gigabit-Ethernet ports. A second twelve port Cisco 2950 switch was installed in the server cabinet, to connect each of the classroom switches to, as well as the three servers and the router. The forty-eight port switch connects to the twelve port switch via one of its Gigabit-Ethernet ports, although it will not run at the full Gigabit speed, since the corresponding port on the other switch is only capable of Fast-Ethernet speeds. In order to guarantee connectivity among the servers during a power outage, these two switches and the router use a rack mounted uninterruptible power supply (UPS). This should allow them to complete any network transactions among themselves before they cleanly shut themselves off in an emergency.

Each of the Cisco switches in the central server cabinet as well as the other classrooms are configured for fine-tuned performance and security. All Cisco switches enable the Spanning-Tree protocol by default, in order to protect against logical loops and broadcast storms [1]. In order to function, Spanning-Tree sends out an update every two seconds, and will not activate any switch port for thirty seconds while it listens for and learns about other possible switching loops in the network [2]. Since the CIT network topology doesn't have any physical loops cabled into it, Spanning-Tree was safely turned off to prevent the Spanning-Tree update from taking up resources unnecessarily. Also, to prevent the thirty second delay before a port is activated, a Cisco proprietary feature called PortFast was also configured on all access ports, to allow them to transition immediately into forwarding [3]. Further, each switch was configured with an IP address, and configured to allow remote administration, but only from a few select IP addresses configured in an Access Control List (ACL). To further enhance security, the default web interface was turned off, and all passwords on the switch are encrypted.

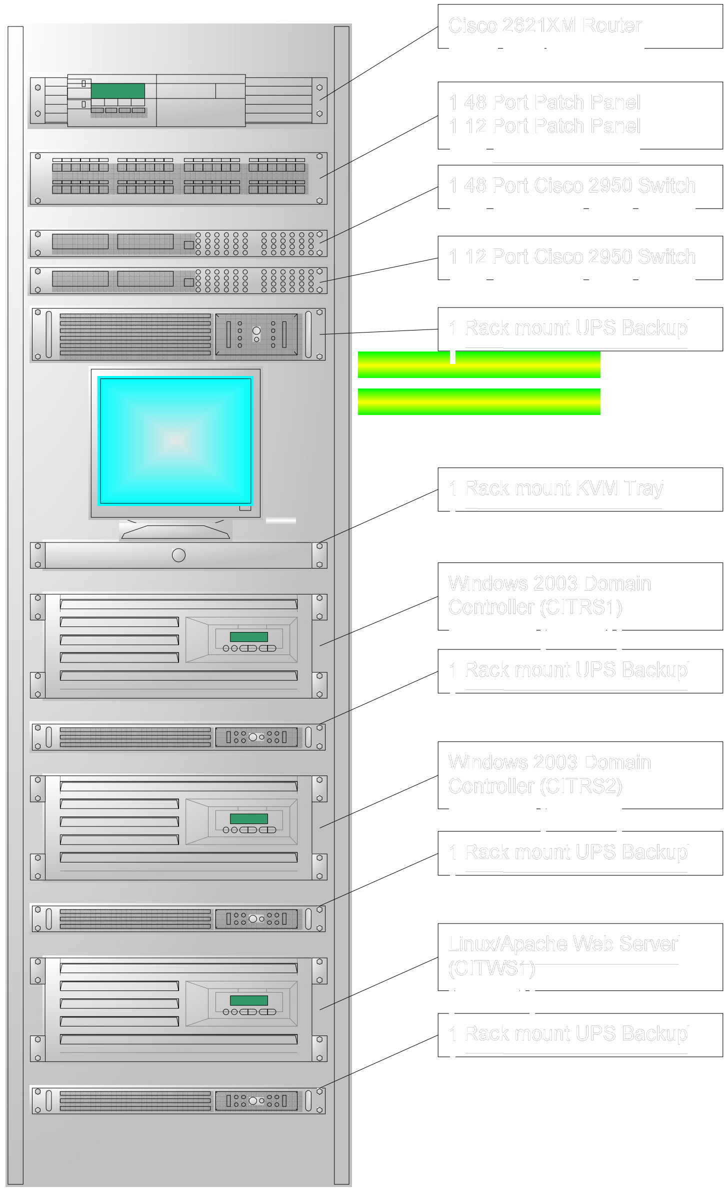
The CIT router is also configured for fine-tuned performance and security: This router has two Fast-Ethernet interfaces, and is configured to use both dynamic Network Address Translation (NAT) with overloading, and static translations. Network Address Translation is a process whereby a router can swap out a private IP address (as defined by RFC 1918) in an IP packet, with a legitimate publicly routable IP address. It has the advantage of allowing several stub networks to share an overlapping IP addressing scheme without causing conflicts [4]. Overloading a NAT translation refers to the ability of a router to translate several IP addresses from a privately addressed inside network to one or a few public IP addresses. This is possible because in addition to translating the individual IP addresses, the router also tracks the TCP or UDP source and destination port numbers associated with each data flow. Dynamic NAT makes these translations on the fly, and only holds them in memory temporarily. Typically, when NAT is implemented, the privately addressed network segment can access resources on the Internet, but because the translations are dynamic, computers on the Internet cannot access the privately addressed computers, thus providing enhanced security. If an Internet resource is hosted on a privately addressed computer, Internet devices can access that resource through a static translation, which maps a public IP address and TCP or UDP port number to a private IP address and port number permanently [5].

In addition to providing NAT services, the CIT router also secures remote administration by restricting those connections to only a few trusted IP addresses secured by an ACL. To further enhance security, the default web interface was also turned off, and all passwords on the router are also encrypted. The IP Proxy ARP service was also disabled.

In addition to the physical cable terminations and the router and switches, the central server cabinet also houses two Windows 2003 domain controllers, as well as a Linux web server used to host web based curriculum (http://cit.wvup.edu/), a rack mount KVM tray providing a shared keyboard, monitor, and mouse, and three UPS' (See Figure 3.2). All three servers utilize a redundant power supply, and connect one power supply to one UPS, and the other to a second UPS, for added protection. To improve performance, the operating system was installed on one drive connected to a single hard drive controller, and a separate RAID 1 (drive mirroring) array with a separate controller card was used for data storage to increase performance and reliability.

In order to administer each server, a rack mounted KVM unit was installed. These rack mounted units take up minimal space, and allow the same keyboard, video monitor, and mouse to be shared among all three of the servers.

Figure 3.2 - Diagram of the CIT Central Server Cabinet



3.4 Configure Servers and Workstations

Once all the electricity and physical network was installed, the computers had to be installed in the new classrooms, and computers in all classrooms configured with an operating system (Windows XP) and several key software applications. This was deployed across the network from one of the central servers installed in the server cabinet. In order to accommodate this, two new servers were installed and configured with Windows 2003, using Active Directory and the Remote Installer Service.

3.4.1 Servers

Standard practice for the WVU-Parkersburg IT department has been to custom-build new servers, and the new CIT servers were no exception. These servers use redundant power supplies, the latest CPU and RAM, and dual network cards, as well as multiple hard drives for the operating system and data storage, and a DVD-burner and USB ports for external hard drives and other devices for data backup. The current server operating system supported by the IT department is Windows 2003 Server, running Microsoft Active Directory. This is a cutting edge server operating system, with good support for hardware and network management. It also integrates extremely well with Windows XP as a client, and is easy to manage. It is also one of the primary technologies taught in the CIT and BAT programs, and provides an opportunity to showcase topics taught in class.

The operating system uses standard installation components, and was installed on a dedicated hard drive. Once the basic operating system was installed, Active Directory was installed to provide “centralized, secure management of an entire network” [6]. Active Directory provides authentication and authorization for users and computers on the network, and establishes a framework for all other network services to function. Some of the services necessary include: Domain name services (DNS), Group Policy, file and print sharing, automatic IP addressing via DHCP, automatic client OS installation with Remote Installation Service (RIS), operating system patch management through

WSUS, and security auditing with the latest version of the Microsoft Security Baseline Analyzer.

In order to balance the load required by all these services, and to provide redundancy, two servers were recommended. Some services were installed on both servers, including Active Directory and DNS. Other services were only be installed on one server or the other, in order to distribute the workload as evenly as possible.

The first critical service was DNS. DNS is required by Active Directory, and if it is not installed when Active Directory is installed, the Active Directory installation will install and configure it based on the requirements of Active Directory [7]. DNS is a hierarchical naming scheme that maps a computer name to its associated IP address. In order to configure DNS, two things must be in place: First, there must be an IP addressing scheme, and second, there must be a naming scheme. Since the CIT router is providing NAT services, the network was (and should be) addressed with a private IP address. Along with the private IP addressing, a private DNS zone was also recommended for security. The CIT network was configured using the DNS zone *cit.wvup.local,* since the top level zone *.local* is reserved for private use [7].

The private class B IP address 172.30.0.0/16 was chosen, because it provides a tremendous amount of growth, and an opportunity to include information in the IP address about the location or function of the device being addressed. With a class B IP address, the third and fourth octets of the address are available for the administrator to control and assign to hosts [8]. Each of the servers were addressed with 1 in the third octet, and the server number in the fourth octet. For other devices such as printers, the third octet will always be 20, and the fourth octet will be the room number. For switches, the third octet will always be 10, and the fourth octet will be the room number. For workstations, the third octet represents the room in the CCAT where the computer is located, and the fourth octet will represent the individual computer itself.

Computer names should be intuitive, and representative of the function of the computer. For the two Windows servers, the name CITRS1 and CITRS2 were both chosen. The name represents the fact that the server is on the CIT network, it is a resource server, and the number provides scalability. Printers are named based on the room number, so that a printer in room C217 will be named C217Printer. Each room in the CIT network is dedicated to teaching one primary topic from the curriculum, so a naming convention reflecting this was chosen. The room functions are as follows: C119 is used to teach the cabling curriculum, C123 is used to teach the A+ computer hardware curriculum, C127 is used to teach the Microsoft client and server curriculum, C217 is used to teach the Cisco CCNP curriculum, and C221 is used to teach the CCNA curriculum. Computers in a particular room are named based on their curriculum topic, along with their station number. For instance, the first workstation in C123 is called Aplus1, while the third computer in C217 is called CCNP3, and so on. This naming convention is scaleable and predicable, and can easily grow if need be. While not all rooms have twenty-four student workstations, in the future this may be a possibility, so each instructor computer is addressed with the room number in the third octet, and the fourth octet will always be 25. Student and instructor workstations will be automatically assigned static IP addresses through a local computer group policy startup script that will read the address from a file based on the computer name. Table 3.1 describes the mapping of names to IP addresses:

Table 3.1 IP Addressing scheme

Name	IP Address	Device	Location
CITRS1	172.30.1.1	Windows 2003 Server	Server cabinet
CITRS2	172.30.1.2	Windows 2003 Server	Server cabinet
Webserver	172.30.1.3	Linux Server	Server cabinet
CITRouter	172.30.1.255	Cisco 2621XM Router	Server cabinet
C119Switch	172.30.10.119	Cisco 24 port switch	C119
C123Switch	172.30.10.123	Cisco 24 port switch	C123
C127Switch	172.30.10.127	Cisco 24 port switch	C127
C219Switch	172.30.10.219	Cisco 48 port switch	Server cabinet
C220Switch	172.30.10.220	Cisco 12 port switch	Server cabinet
C119Printer	172.30.20.119	Classroom printer	C119
C123Printer	172.30.20.123	Classroom printer	C123
C127Printer	172.30.20.127	Classroom printer	C127
C217Printer	172.30.20.217	Classroom printer	C217
C221Printer	172.30.20.221	Classroom printer	C221
Cable1	172.30.119.1	Cabling workstation	C119
Through			
Cable25	172.30.119.25	Instructor workstation	C119
Aplus1	172.30.123.1	Aplus workstation	C123
Through			
Aplus25	172.30.123.25	Instructor workstation	C123
MCP1	172.30.127.1	Microsoft workstation	C127
Through			
MCP25	172.30.127.25	Instructor workstation	C127
CCNP1	172.30.217.1	CCNP workstation	C217
Through			
CCNP25	172.30.217.25	Instructor workstation	C217
CCNA1	172.30.221.1	CCNA workstation	C221
Through			
CCNA25	172.30.221.25	Instructor workstation	C221

Another important feature of DNS is the ability to resolve names in zones that are not locally configured on the DNS server. Typically, this is done by configuring a zone for the global root DNS server. When configured this way, the zone file mapping root DNS servers must be updated several times a year. Since these servers are located around the world, response times can sometimes be slow as well. Another method though is to simply forward DNS requests to another upstream server in your organization. This is referred to as DNS forwarding, and tends to be faster, since the servers responding to the requests are closer [9]. It also allows name resolution of other privately addressed DNS zones within your organization. In order to take advantage of these features, the CIT network DNS servers were configured to forward requests to the main WVU-Parkersburg DNS Servers.

Once Active Directory and DNS were configured, user accounts and groups were created, along with group policy settings to provide security policies. To simplify security rights and user administration, a group for each classroom function was created, based on the function name, and a separate group for instructors and staff was also created. One new feature available in Active Directory is the organizational unit. “Organizational units (OUs) are used as containers to logically organize directory objects such as users, groups, and computers in much the same way that folders are used to organize files on your hard disk.” [10] “Group Policy settings define the various components of the user's desktop environment that a system administrator needs to manage” and are inherited hierarchically from the Active Directory site, domain, and then the Organizational Unit. Group Policy settings are inherited from any of these containers that are above the user or computer object in the associated hierarchy. Since the CIT network is located in the CCAT, there is only one site, and likewise there is only one domain (cit.wvup.local). In order to provide structure and simplify administration, the organizational unit structure in figure 3.3 was configured.

Figure 3.3 CIT Domain and Organizational Unit structure

This structure allows the same group policy settings, applied at the Classroom OU, to be inherited by all student user accounts and workstations. This provides a single point of configuration to simplify settings and avoid mismatched policies. Another benefit of this design was the ability to block inheritance at any OU. This could be useful when IT personnel need to work on computers in one room while classes are being held in other rooms. Group Policy settings exist for user accounts, and computer accounts, and with this structure settings for just the users, or just the computers, or both can be easily disabled or enabled in any one room or any combination. By putting the instructor stations and the IT staff in a different OU at the same level as the Classroom OU, a less restrictive set of policies can be used to give instructors and staff greater control over their workstations. [11]

Another critical network service the servers provide to student workstations is file and print sharing. File sharing refers to the ability of a Windows server to share a folder across the network so other computers on the network can access the data in that folder. Windows servers have very basic file sharing permissions, including Full Control, Change, and Read-Only for all users. Fortunately, the underlying file system permissions of the NTFS file system, which can be highly customized on a per-user or per-group basis, also apply across a network. This being the case, share permissions were always be set to Full Control, and NTFS permissions were used on the file server to secure and customize access to sensitive data. Printer sharing involves installing a network printer on the server, and then sharing it through the server to workstations on the network. Windows 2003 servers also have the ability to publish print drivers for several different operating systems when the server shares a printer. Since the only operating systems using the printers will be Windows XP and Windows 2003 server, those are the only print drivers that were installed [12].

CITRS1 was selected as the network's primary file and print server, and had several file shares configured on its RAID 1 array. See Table 3.2 for a complete reference of file shares.

Table 3.2 List of file shares on server

Share Name	Purpose	Mapped to drive	NTFS Permissions Students	NTFS Permissions Instructors & Staff
CourseFolders	A share for students and instructors to store and exchange data on the network	P for students, V for instructors	Full Control	Full Control
Deployment	Publish software installation files	S for instructors	Read Only	Read Only
NetAdmin	Scripts and programs used by administrators	Q for instructors	No Permission	Full Control
Testing	Instructors can publish exams for students	T for students and instructors	Modify	Full Control
Private shares	Private shares for instructors and staff only - hidden with a $ at the end of the share name	P for instructors	No Permission	Individual Instructors will have full control

The next critical service for the network to function properly was the Remote Installer Service, which provides a streamlined way to deploy the Windows XP Professional client operating system, along with pre-installed and pre-configured application software. This service also requires the DHCP service to function properly. Both of these services run on the CITRS2 server. To work effectively on the number of workstations in the CIT network, the Volume License version of Windows XP Professional was recommended. RIS and DHCP both are technologies taught in the CIT and BAT programs, and using them provided another opportunity to showcase topics taught in class.

Since DHCP is a pre-requisite of the RIS service, it was configured first. DHCP provides a way for administrators on a network to automate the assignment of IP addresses to client computers. When a computer boots up and is configured for DHCP, it sends out a broadcast looking for a DHCP server. When a DHCP server receives this request, it can respond by offering an address in its pool of available addresses, along with other information such as DNS servers and a default gateway. RIS uses DHCP to give client computers an address when installing the client operating system, so the client computer can communicate with the RIS server and download the operating system image from the server and install it locally. On the CIT network, DHCP and RIS were both installed on CITRS2, and DHCP was configured with a range of addresses of 172.30.2.1 through 172.30.2.255 for its DHCP pool. [13]

The RIS service was first introduced in Windows 2000 Server, and "enables you to create, maintain, and quickly install identical operating system and software configurations on multiple remote client computers with a predefined level of end-user interaction." [14] This enables all student workstations to have an absolutely identical configuration, so that a student will always be able to go to any computer on the network and find the exact same applications and configurations in the exact same place, every time.

Another advantage of RIS is its ability to work with various degrees of automation when installing the client operating system. For the CIT network, a completely unattended installation is the ideal, and was configured for all clients on the network. This involved pre-staging every computer account in Active Directory, by manually creating the computer account under the correct OU and assigning it the physical machine’s universal unique identifier number (UUID) [15]. By pre-staging the computer account, RIS can easily assign whatever name the administrator chooses to a computer, by simply looking up the UUID of the client computer in Active Directory when the install starts, and giving it the computer name the server administrator pre-configured.

Once the computer accounts were pre-staged, an unattended answer file was created to provide interactive information to the Windows XP Professional setup process. This file provides information such as the Windows XP license key, and answers to other prompts the user would normally provide during an install, such as the Administrator account password and the time zone the computer is located in. With this, once the installation starts, no user input is required until the operating system and associated software has been completely deployed and the computer reboots.

The next two services were both necessary to provide security to the users and workstations on the network. The first is a relatively new add-on service available from Microsoft as a separate download, called Windows Software Update Service, or WSUS. WSUS is a patch management service that allows an administrator to automatically download and deploy operating system and application software patches as they are released by Microsoft. By using the WSUS service, Internet bandwidth usage was minimized, because only the WSUS server actually downloads updates from Microsoft, while all of the clients on the network then download the update from the local WSUS server. Another key advantage of WSUS is its ability to automatically approve critical and security updates through a customized Group Policy administrative template. This ensures that as soon as Microsoft releases a patch for either Windows 2003 Server or Windows XP Professional, it will be approved and installed on all affected servers and workstations in the CIT network [16]. This greatly reduces the network's vulnerability to viruses, malware, and spyware.

The other security service implemented was the Microsoft Baseline Security Analyzer service (MBSA). "MBSA 2.0 is an easy-to-use tool that helps small and medium businesses determine their security state in accordance with Microsoft security recommendations and offers specific remediation guidance." [17] The Microsoft Baseline Security Analyzer can be used from a central server to "detect common security misconfigurations and missing security updates on your computer systems." [17]

3.4.2 Student Workstations

Student workstations were installed with Windows XP and a wide variety of application software used in various classes. As mentioned before, the Windows XP installation was done through RIS. The first stage of this process is to select a computer that is representative of the hardware that the operating system image will be deployed on. Since each classroom has an identical set of computers in the room, one computer from each room was chosen on which to build the image. This is necessary because RIS cannot deploy an image to a computer with a significantly different hardware configuration. This is a major drawback of RIS, but unavoidable, unless a similar commercial package is selected.

Once the computer the image was built on was selected, the basic Windows XP Professional operating system had to be installed on it. One common mistake made by administrators new to RIS is to use a CD installation to build the image with. In order for the image to upload to the RIS server successfully, it must be built with a Windows XP install from the RIS server. Due to this restriction, the first step was to do a standard Windows XP install from the RIS server to the target workstations, and only install the components of Windows XP needed by students and teachers. Once this was completed, the operating system was then customized for performance and updated with the latest service packs and hot fixes.

In order to provide the same configuration and experience in every class, the configuration must work effectively and efficiently on the slowest and oldest hardware currently used in the network. To accommodate this, the same software applications were installed in all classrooms, and the user interface was configured exactly the same for all users. By doing this, a student or teacher should be able to go to any classroom and have any program they may need. By having a unified configuration, support costs and overall TCO were reduced.

After discussing the requirements for each class in the curriculum with the various full-time and part-time instructors, Table 3.3, listing applications, and their purpose, was assembled.

Table 3.3 Student Workstation Applications

Application	Description
Adobe Acrobat	An application and web browser plug-in for viewing PDF files
Adobe Flash	A web browser plug-in for viewing Shockwave Flash animations - necessary for the Cisco online curriculum
Apple QuickTime	A web browser plug-in necessary for viewing Horizon Wimba Live Classroom content.
Browse Control Client	An application that can restrict access to the Internet, based on settings in the Browse Control Server, which will be installed on the Instructor computer in each room
CCleaner	A freeware tool for removing cookies and temporary internet files from a computer - useful for removing spyware and some malware
Cisco Packet Tracer	A free flash based application that can simulate several routers and switches, and allows students to practice configuring these devices in the simulated environment
Ciscopedia	A Windows help file reference for the Cisco router and switch IOS
Examview Player	An application that allows students to take computerized exams built with the Examview Pro program
HyperTerminal PE	A free terminal emulation program used to access the console and configure Cisco routers and switches
Java	A web browser plug-in that allows applets to run - necessary for WebCT
Microsoft Office 2003	A suite of applications for general productivity, including in particular Word, Excel, and PowerPoint
Microsoft Virtual PC	A free virtual machine manager that emulates all of the hardware of a regular computer through software - this allows two or more operating systems to run simultaneously on the same computer
Microsoft Visio	An application for drawing diagrams and flowcharts
PDF Creator	A free open-source application that allows any document to be converted to a PDF through the printing subsystem
SIW	A free tool for collecting system documentation
Spybot Search & Destroy	A free tool for finding and removing spyware and malware
Symantec Anti-Virus	An enterprise class anti-virus application - this is provided through a site license from the WVU main campus
TightVNC	A free tool for remotely controlling and interacting with a client computer - similar to remote desktop

In addition to the software in Table 3.3, several tweaks and optimizations were made to the standard Windows XP installation to improve performance. These were taken from the Windows XP Tweaking Guide available at the website http://www.tweakhound.com/, and are listed in Table 3.4.

One of the most important applications available to the CIT program is the Microsoft Virtual PC program. This program emulates all of the hardware of a regular computer through software, including an AMI BIOS, Intel 440BX motherboard, S3 Trio 64 video card, SoundBlaster sound card, DEC Ethernet card, and a single file that acts as a virtual hard drive [18].

Virtualization provides a unique opportunity for teachers to provide a real world environment for students to gain practical, hands-on experience in the classroom. With virtual machines, each student in a classroom can have their own dedicated computer with which to do labs and experiment with various configurations. The only thing necessary is to create separate virtual machines in software, and stay within the constraints of drive space and RAM provided by the host OS. Without the use of virtual machines, the only way to provide an equivalent real world environment is to use removable drive trays and provide each student with their own physical hard drive, or to duplicate an entire computer lab for students to use as a working test environment, both of which are prohibitively expensive and do not scale very well. This application provides the perfect opportunity for students to work with the real operating systems they are studying in the various Windows and Linux operating systems classes, and gain practical hands-on experience implementing real-world scenarios. One of the best places to use virtual machine technology though is in the Cisco Networking Academy classes.

By pre-configuring a virtual machine with Windows XP and key software packages used in the Cisco Academy hands-on labs, students can have a computer setup that will be

Table 3.4 Tweaks and Enhancements to Windows XP

Action	Description
Revert to Classic Theme	This change will reduce the graphical resources used by Windows XP
Turn off Windows Security Center	This change will free resources that Windows would use to verify security settings that are in place elsewhere. For instance, the CIT router acts as a firewall, Semantec AV is already installed, and Windows updates are handled through WSUS.
Turn off Visual Effects except drop shadow and smooth screen fonts	This change will reduce the graphical resources used by Windows XP
Disable Error Reporting	This change will free resources by eliminating a service students and faculty don't need
Turn off System Restore	This change will prevent the operating system from making unnecessary backups. All important data will be stored on the file server.
Turn off Remote Assistance	TightVNC will provide remote control and connectivity, with less overhead
Turn off Indexing	This change will reduce the CPU, memory, and hard drive resources used by Windows XP
Turn off System Sound	This change will free resources that are not needed, since no student computers have speakers
Turn off Hibernate	This change will improve operating system performance
Adjust System Resources	This change involves turning off all unnecessary services. This will actually be done in the Classroom Group Policy, so the changes will be identical on all computers.
Clear the Prefetch folder	This will reduce the disk space needed to upload and download the image
Remove unnecessary programs from Windows Startup	This will reduce the disk space needed to upload and download the image, as well as reduce security vulnerabilities.
Run Ccleaner & Spybot	This will remove temporary Internet cache, cookies, and spyware
Defragment C: Drive	This will re-organize the data on the hard drive so it is contiguous, which will improve performance.

identical to the systems they will use in the workforce. When this setup is combined with the Virtual PC undo disk feature which wipes out any changes a student makes when the virtual machine is shut down, teachers and students have a nearly perfect learning environment. The Cisco Virtual Machine was configured with another install of Windows XP Professional, with the same tweaks and enhancements as the student workstations applied, but with a different set of software installed. The software needed by students doing Cisco Academy labs is listed in Table 3.5.

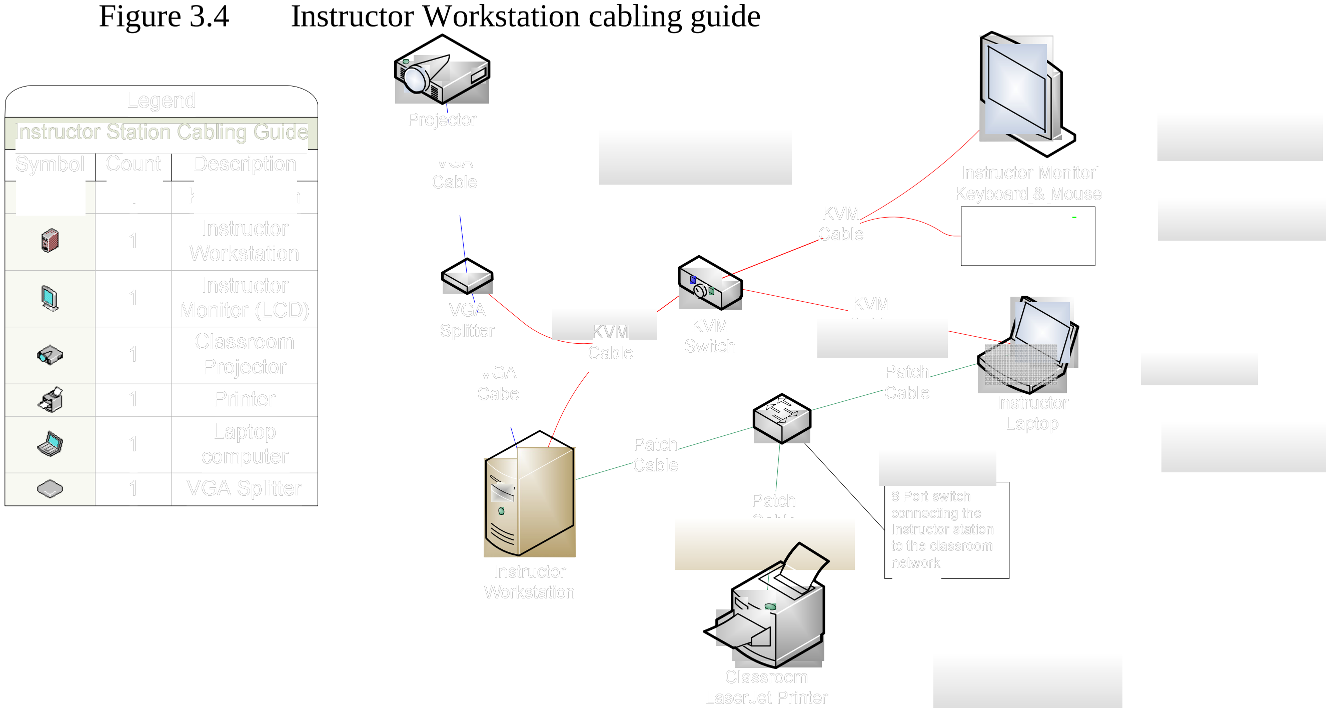
Table 3.5 Cisco Virtual Machine Applications

Application	**Description**
Adobe Acrobat	An application and web browser plug-in for viewing PDF files
Cisco Configuration Register Decoder	A free application from Cisco to tell administrators what effect a register setting will have on a Cisco router
Ciscopedia	A Windows help file reference for the Cisco router and switch IOS
Ethereal	A free and open source application to capture packets on a network
HyperTerminal PE	A free terminal emulation program used to access the console and configure Cisco routers and switches
Kiwi syslog daemon	A free server to collect syslog messages from network devices such as routers and switches
Microsoft Word Reader	A free application for viewing Microsoft Word documents
Shared Folders	A feature of Virtual Machine Additions, which allow a folder in the virtual machine OS to be connected to a folder on the host OS
SolarWinds TFTP Server	A free TFTP server used for transfering Cisco IOS and configuration files
VM Additions	A free add-on to Virtual PC, which provides mouse pointer integration and shared folders.
WinPcap	A free and open source packet capture driver - necessary for Ethereal

3.4.3 Instructor Workstations

Instructor workstations have an additional set of requirements due to their special functions in the classroom. The instructor station has a somewhat complicated cabling setup, which combines a VGA splitter and a KVM switch to allow an instructor to use the instructor station or a laptop with the monitor and overhead projector simultaneously. By installing a small workgroup switch at the instructor station, the instructor's computer, classroom printer, and the instructor's laptop can all use the CIT network at the same time. Below is a cabling guide for all instructor stations:

Figure 3.4 Instructor Workstation cabling guide



Each instructor station has the RIS image that was built for the student workstations in that room installed as a starting point. In addition to the standard set of student software applications, instructor workstations will also have the software listed in Table 3.6 installed.

Table 3.6 Instructor Workstation Applications

Application	Description
Audacity	A free and open source program for recording sound. When combined with the LAME MP3 encoder, it can save sound to MP3 format. Useful for instructors who want to record lectures and distribute them as podcasts.
Browse Control Server	An application that can control student workstation Internet access during lectures, exams, and labs
ExamView Pro	An application for building and grading computerized exams
Lame MP3 Encoder	A free and open source driver that encodes sound to MP3 format. Used in conjunction with Audacity
Microsoft Producer	A free add-on to Microsoft PowerPoint that allows instructors to create interactive recorded lectures with slides
Nero CD/DVD burning software	An application for burning audio, video, and data CD's and DVD's
SetVM Script	A script to control access to the virtual machines on the student workstations.
TrueCrypt	An application that allows hidden and encrypted volumes on a workstation or a USB Flash drive. This will allow instructors to keep information confidential and protected.

The SetVM script is a batch script that was written by one of the faculty members to control student access to the virtual machines (See Appendix A). Faculty and staff have expressed concerns in the past about students having access to the virtual machines while lecturing, where they can install games and have full administrator access. Students in the past have ignored lectures and distracted themselves and their neighbors by playing solitaire or other non-classroom activities when given this access. Another major concern is that the operating system installed in each of the virtual machines has no set policy for anti-virus or Windows updates, and as such, the virtual machines are very vulnerable to Internet based attacks. For these reasons, a way to restrict access to the virtual machines was created.

When the SetVM script runs, it first executes a Wake-On-Lan program to start all of the computers in a classroom over the network. Next, it prompts the instructor to either allow students access to the virtual machines, or deny access to the virtual machines. Based on the selection, the script will go to one of two sub-routines. If the instructor chooses to allow access to the virtual machines, the script will start a count-controlled loop, and map a network drive to the hidden administrative share on each student workstation (C$). This is possible because the Active Directory Domain Security group Instructors is a member of every student workstation's local Administrator's group. Once the student workstation's drive is mapped on the instructor computer, the cacls.exe command then grants file system permissions to the student group, and put a shortcut to Virtual PC on the desktop. The script then unmount's the network drive, and connects to the next computer to repeat the process until it has connected to all twenty-four computers. When it has done this, the script then telnets to the switch in the classroom using the telnet scripting tool (TST10.exe), and puts all of the student ports in a non-routable VLAN, preventing them from accessing the Internet.

If an instructor chooses instead to run the script with the deny option, the script will first telnet back into the switch and put the workstations back in the same VLAN as the rest of the network, again using the telnet scripting tool. Once this is done, the Instructor station can once again connect to the student workstations, and proceeds to map each workstation's administrative share as a network drive. The script again uses the cacls.exe command to remove file system permissions, and remove the shortcut from the desktop. The script then uses the taskill.exe command to shut down any active Virtual PC sessions, and then unmount's the network drive, and connects to the next computer to repeat the process until it has connected to all twenty-four computers.

By doing this, the script allows students to use Virtual PC without Internet access, keeping the virtual computers and the student workstations safe from viruses and spyware on the Internet. This system also prevents some students from using the virtual machines when they should be doing class work.

4 – Critical Success Factors

Based on discussions with the CIT and BAT faculty, program administrators, IT and maintenance personnel, as well as the triple constraints of the project; five critical success factors were selected. They include: The performance of the new network and workstations, increasing the capacity and availability of classrooms, providing more robust and secure access to and from the network segment and the rest of the school, completing the project with no interruption to classes, as well as completing the project within the projected budget.

The first and most important of the critical success factors was undoubtedly the performance of the new network and workstations. This project was undertaken in order to replace an ad-hoc network with a state of the art network showcasing technologies taught in the curriculum. This new network improved access to equipment by allowing one class to utilize all available equipment, instead of only half of the available equipment. In addition, the safety of the lab was greatly improved, since students are no longer required to move equipment racks into isles between desks and string network and power cables across the floor. These two changes drastically improved the quality and effectiveness of classes taught. This in turn helps student retention and recruiting as well. If the new network did not allow students to access the networking equipment, then the project would not have succeeded.

Another critical success factor was the opportunity to increase the capacity and availability of classrooms. As enrollment increases and the administration add emphasis on room usage in program reviews, the opportunity to increase both the capacity and availability of classes offered a big potential impact. If the new network had reduced class size and/or availability, then the project would not have succeeded.

The next critical success factor was more of a pragmatic issue, of trying to provide more robust and secure access to and from the network segment and the rest of the school. The WVU-Parkersburg administration and IT department have several times expressed concerns that students in the CIT and BAT program are gaining knowledge of computer and network systems that could be easily abused and put the rest of the campus at risk. In addition, there have been several times when the campus has been hit with a network aware virus and spread to or from the CIT computer labs, which in turn greatly impacts computer classroom availability.

By segmenting the classroom network from the rest of the campus, each of these concerns were greatly mitigated, and performance of both networks has been faster, since the new network segment splits the one large broadcast domain into two smaller broadcast domains. If a new virus infects the campus network or the CIT/BAT classroom network, there is a single connection that can be disconnected to protect the other network. Further, by running everything in the new CIT/BAT network through a router and using the WVU-Parkersburg campus network only as an Internet service provider, any student trying to do something malicious to the campus network will have a much more difficult task. If the new network instead reduced the performance or security of the classroom or campus network, then the project would have succeeded.

A further critical success factor involved completing the project with no interruption to classes. If the current or new classes were interrupted, the overall quality and effectiveness offered to students would have been negatively impacted. In order to prevent this, the project was undertaken over a summer break, when no CIT or BAT classes were scheduled, and the affected classrooms were not in use by students. If the project ran into the fall semester, it would not have been considered a success.

The last critical success factor involved completing the project within the projected budget. If the project ran over, there was no way for the department to raise more monies, since tuition, lab fees, and departmental budgets are essentially fixed annually. A rainy-day percentage was planned and built into the budget, but if the project ran over this percentage, it would not succeed.

Each of these factors outlined played a major role in the success or failure of this project. The first three factors were positive goals the project had to achieve, while the remaining two factors were circumstances the project tried to avoid. These success factors were tied directly to the triple constraints due to their potential impact on one or more of the constraints.

5 – Work Breakdown Structure

Once the major tasks necessary to complete the project were identified, they were broken down further into individual tasks, and laid out in the following work breakdown structure. This was the first major planning component of the overall project. With this information, a list of each task and its individual predecessors and successors was built, and time estimates for each individual task were then assigned. With this information, a Gantt chart (Appendix B) and network diagram (Appendix C) were assembled, and the critical path identified.

5.1 Pictorial view of the Work Breakdown Structure

Figure 5.1 Work Breakdown Structure, Part 1

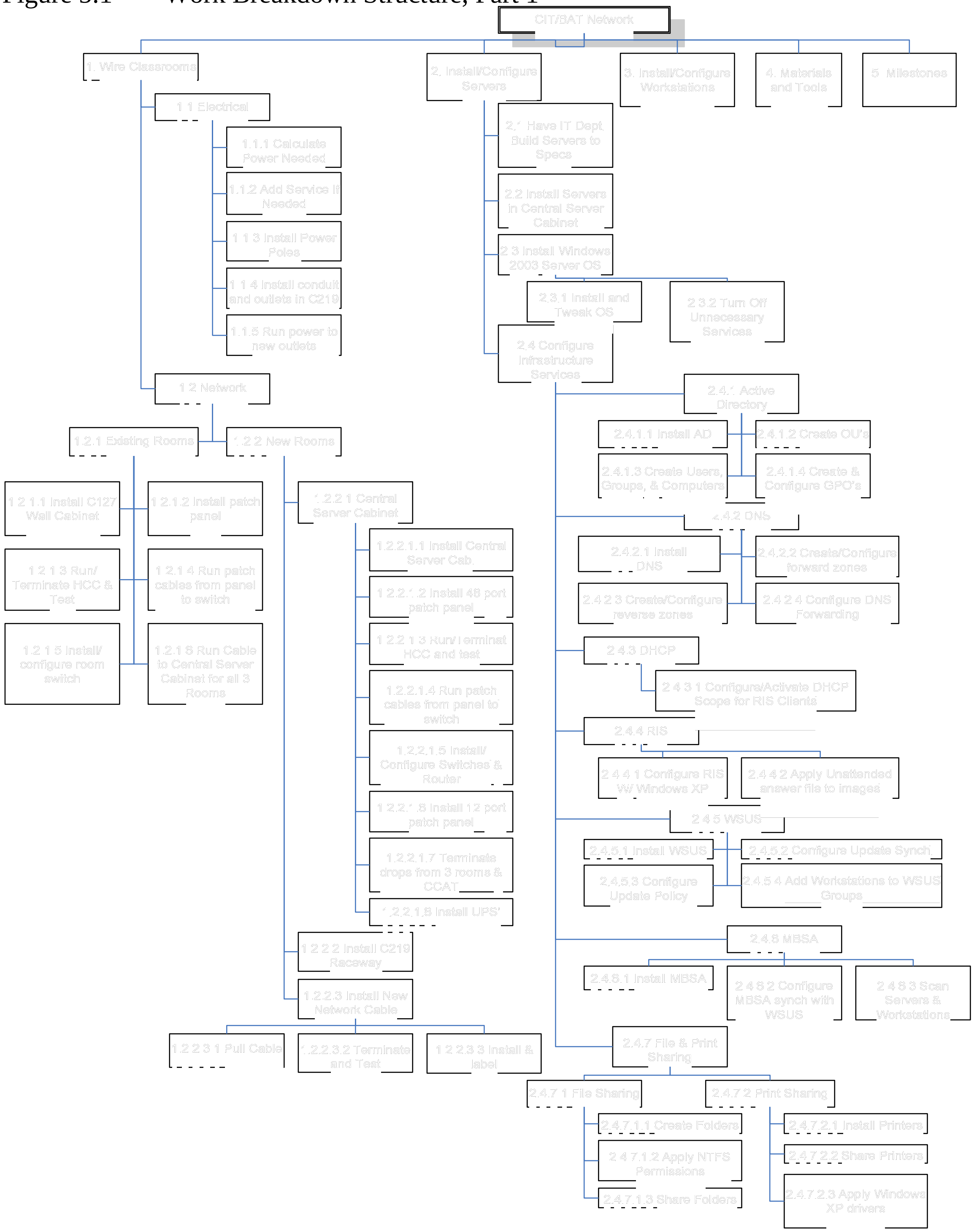
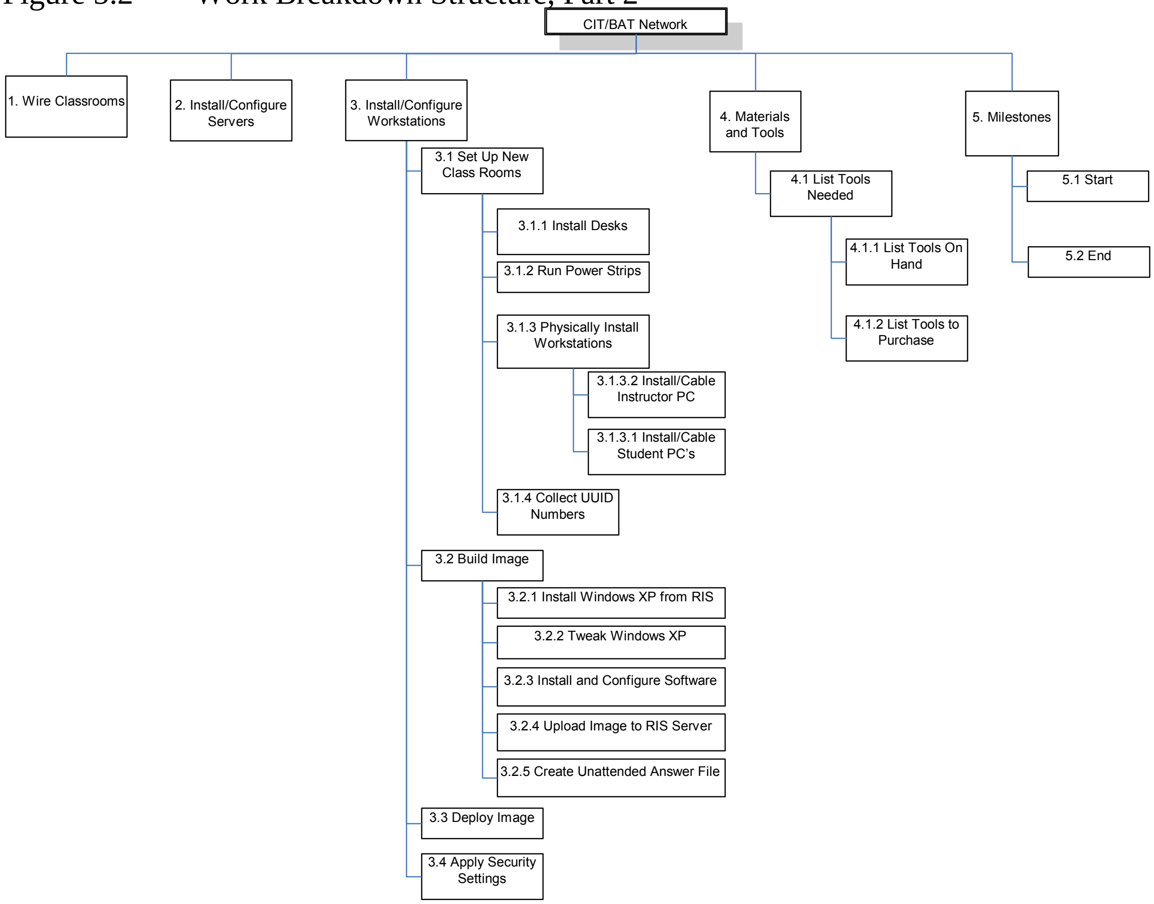


Figure 5.2 Work Breakdown Structure, Part 2



6 – Task Cost and Duration Estimates

6.1 Estimated Labor Costs

Labor cost estimations were based on $20/hr for the faculty member, $15/hr for the maintenance worker, and $7.50/hr for the student worker. The total amount estimated for labor is approximately $5,500. Tasks were assigned to the personnel with the most appropriate skill level. The student worker was used wherever possible; to both provide an opportunity for experience, and to reduce costs. Overtime is not a consideration, since time is the weak driver for the project, and there are six weeks of potential slack between the projected end of the project and the start of the fall semester. Individual tasks and time estimates are listed in Table 6.1 for the maintenance worker, Table 6.2 for the professor, and Table 6.3 for the student.

There were tasks related to the project that were not captured in the estimates, due in part to the nature of project planning and approval at WVU-Parkersburg. For instance, none of the project planning was included or paid for, since the planning must be done before funding is approved by the administration. In addition, many of the tasks and skills needed to configure the workstations and servers were completed with minimal troubleshooting due to the topics being covered in classes and the professor already working out problems when developing labs for students. Faculty at WVU-Parkersburg are not compensated for that type of work, but the skills gained did simplify and streamline the project. Had any of these been included, there would have been a significant potential to go over the projected budget.

Table 6.1 Labor estimates for maintenance

Maintenance	**114.5 hrs**
Add service if needed	4 hrs
Install power poles	16 hrs
Install conduit and outlets in C219	4 hrs
Run power to new outlets	8 hrs
Run/Terminate HCC and test	16 hrs
Run cable to central server cabinet for all 3 rooms	4 hrs
Install C219 Raceway	4 hrs
Pull cable	24 hrs
Terminate and test	16 hrs
Install in surface-mount boxes and raceway, and label	4 hrs
Order electrical materials	1 hr
Calculate power needed	4 hrs
Install wall cabinet (C127)	1 hr
Install desks in new rooms	8 hrs
List Tools on hand	0.5 hrs

Table 6.2 Labor estimates for professor

Professor	**119.5 hrs**
Install and configure switches and router	4 hrs
Have IT Department build servers to specifications	1 hr
Install and tweak OS	4 hrs
Turn off unnecessary services	4 hrs
Create OU Structure	1 hr
Create users, groups, and computers	4 hrs
Create and configure Group Policy objects	16 hrs
Create and configure forward zones	1 hr
Create and configure reverse zones	1 hr
Configure DNS Forwarding	1 hr
Configure MBSA to synchronize with WSUS	1 hr
Scan servers and workstations	1 hr
Install desks in new rooms	8 hrs
Install Windows XP from RIS on each type of computer	2 hrs
Tweak Windows XP	4 hrs
Install and configure software	24 hrs
Upload image to RIS server	4 hrs
Create unattended answer file	1 hr
Deploy image	16 hrs
Apply security settings	8 hrs
List Tools on hand	0.5 hrs
List tools to purchase	1 hr
Order tools needed	1 hr
Install Active Directory	1 hr
Order network cabling and equipment	2 hrs
Order new workstations	4 hrs
Install DNS	1 hr
Install MBSA	1 hr
Install Central Server Cabinet	2 hrs

Table 6.3 Labor estimates for student

Student	181 hrs
Run patch cables from patch panel to switch	1 hr
Install and configure room switch	1 hr
Run/Terminate HCC and test	8 hrs
Run patch cables from patch panel to switch	1 hr
Install 12 port patch panel	1 hr
Terminate drops from other 3 rooms and CCAT	1 hr
Install UPS'	2 hrs
Install Servers in central server cabinet	4 hrs
Configure and activate DHCP Scope for RIS clients	1 hr
Configure RIS with Windows XP Volume License version	1 hr
Apply unattended answer files to images	1 hr
Configure Update Synchronization	1 hr
Configure update policy	1 hr
Add workstations to WSUS groups	4 hrs
Create folders to share	1 hr
Apply NTFS permissions	1 hr
Share folders	1 hr
Install printers on server	1 hr
Share printers	1 hr
Apply Windows XP print drivers	1 hr
Run power strips in new rooms	4 hrs
Install/cable student workstations in new rooms	16 hrs
Install/cable instructor workstation	4 hrs
Collect UUID numbers	8 hrs
Install patch panel	1 hr
Install 48 port patch panel	1 hr
Install WSUS	2 hrs
Install desks in new rooms	8 hrs
Pull cable	24 hrs
Terminate and test	16 hrs
Install in surface-mount boxes and raceway, and label	4 hrs
Install Windows XP from RIS on each type of computer	2 hrs
Tweak Windows XP	4 hrs
Install and configure software	24 hrs
Upload image to RIS server	4 hrs
Create unattended answer file	1 hr
Deploy image	16 hrs
Apply security settings	8 hrs

6.2 Estimated Materials Cost

Many of the materials needed for this project were already on hand. For instance, WVU-Parkersburg already had enough computer desks for the two new classrooms. Another item that saved the project money was the ability to re-use twenty five computers from a CAD lab. The newest version of AutoCAD required new computers, but the computers were still fast enough for most applications. As a result, the CIT program inherited these computers instead of purchasing new computers, saving over twenty-five thousand dollars. Other items such as the overhead projectors were also already in place. For the remaining materials, prices and quantities are listed in Table 6.4 and Table 6.5, and total approximately $53,000. The cost of one new set of computers for one of the two new computer labs was included as a component of this project. It is important to understand that one of the ad-hoc computer labs that was being used by the CIT program prior to this project was due to be cycled anyway, and as such would have had the twenty computers in it replaced whether this project was undertaken or not. Since this project increased the seating capacity of the classrooms, five extra computers were ordered as a result of this project being completed. Materials cost estimates do not include sales tax, since WVU-Parkersburg is exempt from sales tax as a state institution.

Table 6.4 Estimated cost of electrical materials

Item	**Supplier**	**Cost**	**Quantity**	**Total**
Power Poles	State Electric Supply Co.	$100	10	$1,000
Conduit	State Electric Supply Co.	$7	1	$7
Outlets	State Electric Supply Co.	$2.50	10	$25
Electrical Wire	State Electric Supply Co.	$30	4	$120
Circuit Breakers	State Electric Supply Co.	$30	4	$120
Power Strips	Wal-Mart	$10	26	$260
UPS	Office Depot - part number 726325	$550	4	$2,200
Total				$3,732

Table 6.5 Estimated cost of networking materials

Item	Supplier	Cost	Quantity	Total
Cat5e Plenum Grade Cable	State Electric Supply Co.	$150.00	20	$3,000
RJ-45 jacks 400	SF cable part number 68JK-C511	$2.85	400	$1,140
RJ-45 ends – 100	SF cable part number 68PG-6A	$12.50	10	$125
Surface Boxes	State Electric Supply Co.	$4.00	50	$200
2" x 4" Velcro to mount boxes	Lowes - part number 46238	$3.08	25	$77
Faceplates	State Electric Supply Co.	$1.00	100	$100
Servers	WVU-Parkersburg IT Department	$2,000.00	3	$6,000
Raceway – approx 20 feet	State Electric Supply Co.	$500.00	1	$500
Cable Tray – Approx 15 feet	State Electric Supply Co.	$100.00	1	$100
Server Cabinet	BlackBox part number RM2450A with fan and power	$1,350.00	1	$1,350
Wall Cabinet	BlackBox part number RM232A-R2	$550.00	1	$550
Cisco 2950T 48 port switch	Superwarehouse part number WS-C2950T-48-SI	$1,800.00	1	$1,800
Cisco 2950T 24 port switch	Superwarehouse part number WS-C2950T-24	$1,000.00	2	$2,000
Cisco 2621XM Router	Superwarehouse part number CISCO2621XM-DC	$2,700.00	1	$2,700
Patch Panel - 48 port	Superwarehouse part number N052-048	$70.00	1	$70
Patch Panel - 24 port	Superwarehouse part number N052-024	$40.00	1	$40
Patch Panel – 12 port	ComputerCableSource part number PAT-5E-12	$50.00	1	$50
Short patch cables	CompUSA - part number 52161291	$1.50	120	$180
New Workstations - Dell	Dell	$1,100.00	25	$27,500
KVM Switches & Cables	TigerDirect - part number C184-35555	$65.00	5	$325
8 port switch	Office Depot - part number 736771	$50.00	5	$250
Rack mount KVM Switch	RackmountMart - part number LCD1U17-06	$1,100.00	1	$1,100
Total				$49,157

7 – Project Planning and Organization

After carefully planning the project and each tasks predecessor and successor, a Gantt chart (See Appendix B) and network diagram (See Appendix C) were developed to help schedule resources and plan events. After planning each task and estimating the duration of each, the overall duration of the project was calculated at approximately six and a half weeks. Since the summer break is approximately twelve weeks, this provides plenty of slack time in which to complete the project if any problems arise. The key events necessary to complete the project include wiring the new rooms and wiring the existing rooms to connect back to the central server cabinet, setting up the servers with key services, building the student workstation image, and deploying the image to all student workstations.

After carefully laying out each task with its predecessors, successors, and time constraints, the following critical path was identified: Start => Order new workstations => Have the IT department build servers => Install servers in server cabinet => Install and tweak OS => Turn off unnecessary services => Install DNS => Configure DNS Forwarding => Install Active Directory => Install WSUS => Configure Update Synchronization => Configure Update Policy => Install MBSA => Configure MBSA to synchronize with WSUS => Scan Servers and Workstations => Apply Security Settings => End.

8 – Fatal Flaw Analysis

After careful consideration of the critical success factors and brainstorming to consider all possible areas that problems may arise, the following Fatal Flaw matrix diagram, charting impact and probability for all listed events was created:

Table 8.1 Fatal Flaw Analysis

Fatal Flaw Chart	increasing probability of occurrence		
increasing impact to project	1	5	2, 3, 4, 6, 8, 9
	7		

~~**Key:**~~

1. Budget overrun
2. Room capacity
3. Network Performance
4. Network Security
5. Class interruption
6. Electrical outage
7. Missing worker
8. Materials shortage
9. Faulty material

The primary concern while building the new classroom network was the potential for a budget overrun. Since the project was undertaken at a state institution, and budgeting is essentially fixed on an annual or semester basis, if the project ran over the estimate there are no alternative sources of capital available, and the project would only be partially successful or may even fail. In order to accommodate this potential danger, a cushion of 10% was built into the budget, and costs were monitored on a weekly basis compared with estimates. If cost overruns looked likely, a meeting with all key personnel was called, and a plan of action developed to accommodate the specific problem.

The remaining two potential problems were not as much of a concern as a potential budget overrun, but were still important enough to warrant pre-planning. These concerns were the potential for class interruption, and the potential for a missing worker. If a worker was off sick or unavailable for some reason, the project could continue with either the two remaining workers re-arranging tasks that require the third worker to occur later when he or she was available, working overtime to make up the difference, or working flex time later to accommodate all three workers being present. Overall, the overtime option was the least desirable, because it would have had an adverse effect on the budget. If the project ran into the fall semester, it would have a negative impact on classes, and was scheduled to start as early in the summer as possible to avoid this. A slack period of at least two weeks was planned at the end of the project, to be used only in case of an emergency.

9 – Summary

In order to accommodate the growth in the CIT and BAT programs, enhance the learning environment available to students in these programs, and protect the rest of the WVU-Parkersburg campus network, a complete overhaul of the existing classrooms used for these programs was undertaken.

The first component of this was to convert two classrooms originally used to house the Environmental Science A.A.S. program to state of the art computer labs. These two classrooms replaced two smaller lecture rooms which had only an ad-hoc network and limited physical resources for hands-on learning. They also greatly improved safety and access to the network hardware such as routers, switches, and firewalls used to teach by providing a dedicated equipment room in between, where students can access all available hardware. They needed new electrical and network cabling, computer desks, and new computers with all appropriate software installed and configured, as well as an instructor station with educational tools such as an overhead projector, whiteboards, and a classroom network capable printer.

The next major component of the overhaul involved re-wiring three other classroom networks already assigned to the CIT and BAT program, and connecting them back to the same central point as the two new computer labs. Once this was accomplished, then a secure central access point was configured between the CIT/BAT classroom network and the rest of the WVU-Parkersburg campus. Previously, concerns existed that the skills being taught to the IT students in these programs could be used to by a disgruntled student to wreak havoc on the main campus network. In addition, the IT faculty had expressed a desire to separate the campus network in order to minimize security threats such as viruses which had often previously propagated from the main campus, and to provide a greater degree of autonomy which many deem necessary for such a program. This project also provided a unique opportunity to showcase the various technologies and strategies taught in the classroom, in a real world environment.

In order to provide the autonomy and security desired, a new network server and security system were also installed at the server cabinet. This new network server system consists of two new Windows Servers, an existing web server, a central switch which all five classrooms connect to, and a router with enhanced security configuration to route network traffic to and from the new CIT/BAT classroom network. These servers now provide services to student and faculty computers such as: Authentication, file and print sharing, domain name services (DNS), automatic IP addressing through a DHCP server, automatic client installation through the Windows Remote Installer Service (RIS). In addition, security configuration has been highly automated and available through tools such as Windows Group Policy, Windows Software Update Services (WSUS), and Microsoft Baseline Security Analyzer (MBSA) for security.

The final stage of the project involved purchasing where necessary, configuring, installing, securing, and maintaining student workstations in each lab. These workstations connect to the new servers and have all software installed via RIS, and receive configuration and security settings automatically. The ultimate goal was to have each room offer the best possible opportunity for all students to maximize their hands-on learning in each topic through real world experience, while maintaining security and functionality for other classes, other students, and the rest of the campus.

One of the best measures of the project's effectiveness can be garnered from the project's critical success factors. Each of the critical success factors, including performance, capacity and availability of the classrooms, as well as not interrupting classes and securing access to and from the campus network either met or exceeded expectations.

Of the five original objectives of the project, all were met with success. The first three goals, to design and build two new computer classrooms, re-wiring three existing classrooms, and connecting all five classrooms to a central access point, were accomplished during the project, as pre-requisites to the project's completion. All three goals met or exceeded expectations, and have provided a robust and scaleable network that has adapted well to changes since its inception.

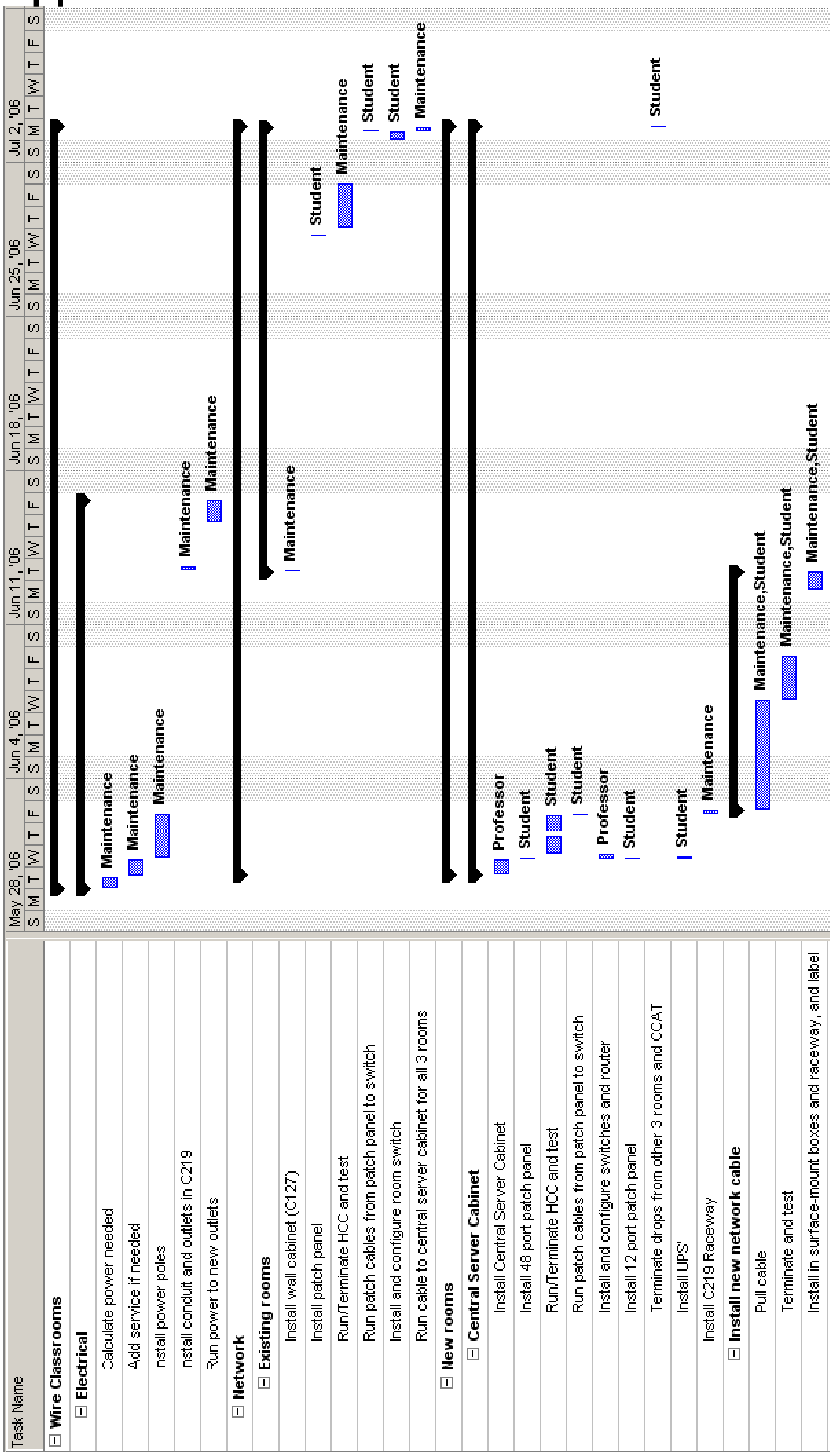
The remaining two objectives included configuring secure access to and from the classroom network to the rest of the school, and to configure workstations for use by students, faculty, and staff. Of these objectives, perhaps the best indicator of success has been the fact that the network has experienced zero downtime due to viruses or other security breaches since it was put in place.

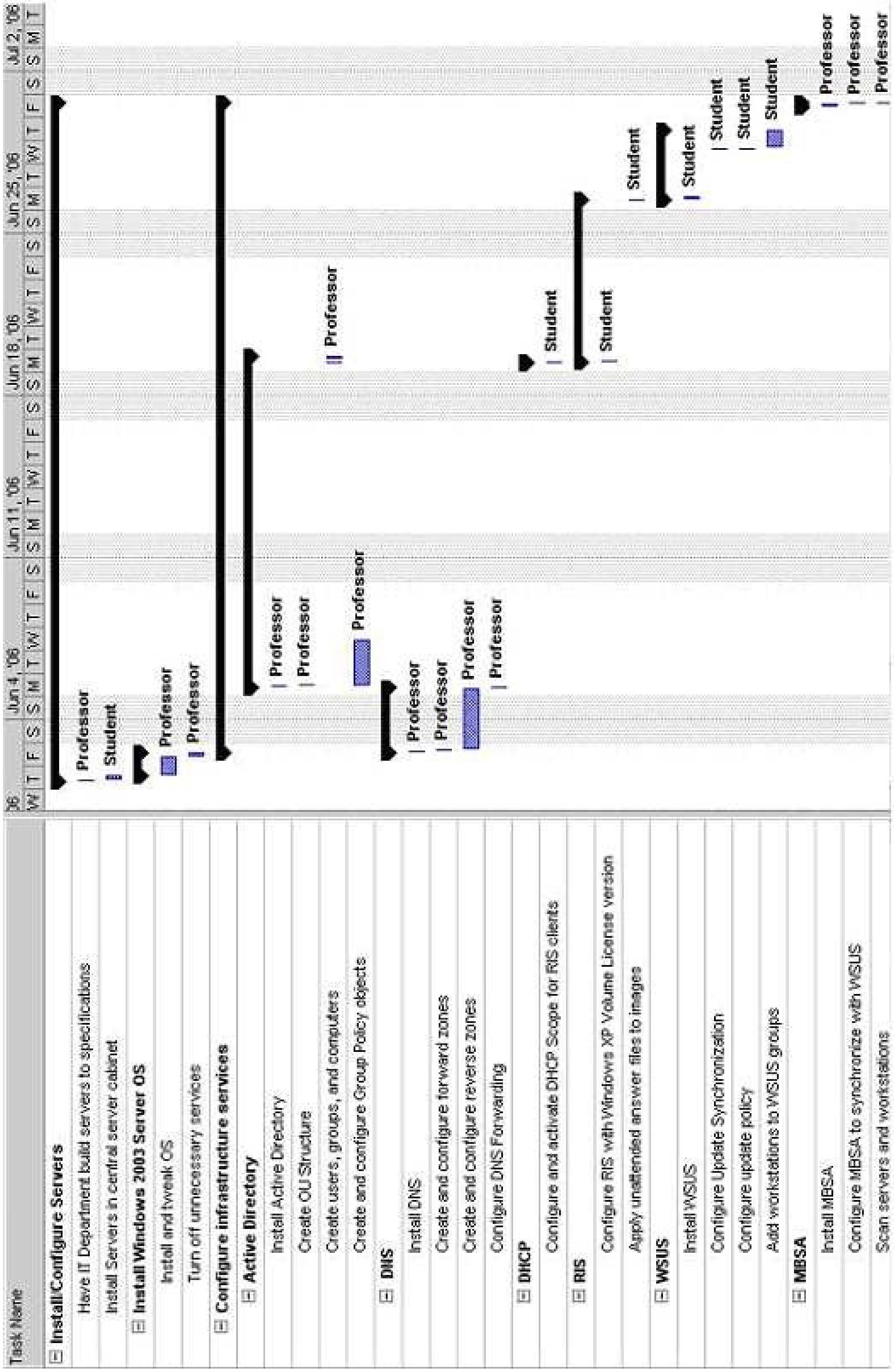
Appendix A – SetVM Script

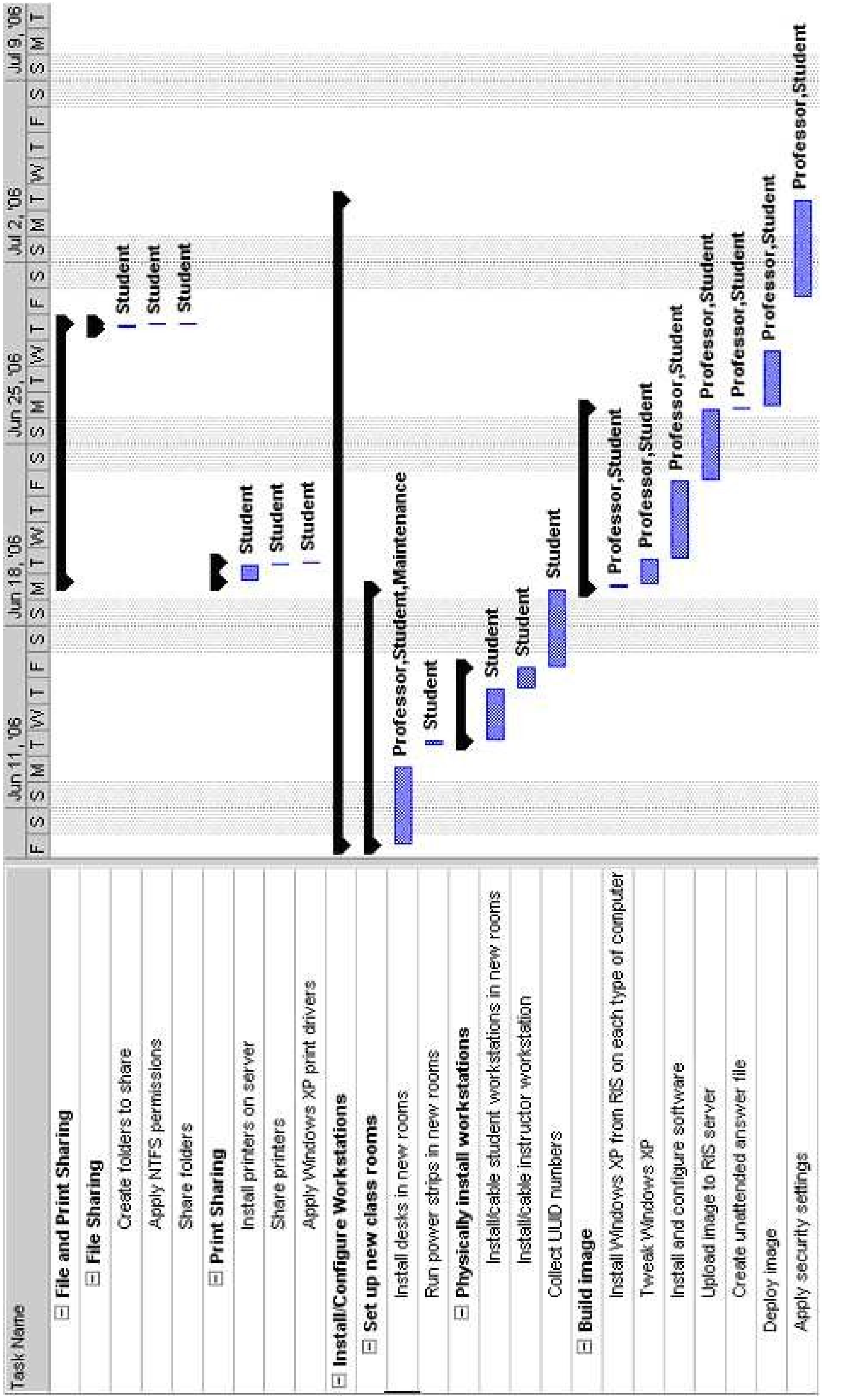
```
@echo off

setlocal

for /f "tokens=1,2" %%I in (C:\SetVM\CCNP.mac) do (C:\SetVM\MC-WOL %%I>temp.txt && echo \
        Waking up %%J )

cls

echo Please wait for all computers to boot up to the logon screen.
echo After allowing students to use the VM, please unplug the room's
echo network connection from the school.
echo.
echo Thank You
echo.

pause

set /A counter=1
set /A choice=0

goto :Menu

:Menu
  cls
  echo This script will control access to the Virtual PC in the CIT CCNP lab
  echo Please choose what type of access you would like to configure
  echo.
  echo 1.) Allow students to access the Virtual Machine
  echo 2.) Deny students access to the Virtual Machine
  echo.

  set /p choice=Please make a selection:

  cls

  if %choice% LSS 1 goto :Invalid
  if %choice% EQU 1 goto :AllowVM
  if %choice% EQU 365 goto :AllowVM
  if %choice% EQU 2 goto :DenyVM
  goto :Invalid

:Invalid
  cls
  echo %choice% was not a valid selection
  pause
  goto :Menu

:AllowVM
```

```
  echo Allowing Virtual PC on CCNP%counter%
  net use H: \\CCNP%counter%\c$ /persistent:no
  cacls "H:\Program Files\Microsoft Virtual PC\Virtual PC.exe" /T /E /P  CCNP:F
  cscript c:\SetVM\MakeShortcut.vbs
  net use H: /delete
  set /a counter +=1
  if %counter% LEQ 24 goto :AllowVM
  if %choice% EQU 1 TST10.EXE /r:denyaccess.txt /o:output.txt /m
  goto :Exit

:DenyVM
  if %counter% EQU 1 TST10.exe /r:grantaccess.txt /o:output.txt /m
  echo Denying Virtual PC on CCNP%counter%
  net use H: \\CCNP%counter%\c$ /persistent:no
  cacls "H:\Program Files\Microsoft Virtual PC\Virtual PC.exe" /T /E /R  CCNP
  cscript c:\SetVM\DeleteShortcut.vbs
  taskkill /S CCNP%counter% /F /IM "Virtual PC.exe" /T
  net use H: /delete
  set /a counter +=1
  if %counter% LEQ 24 goto :DenyVM
  goto :Exit

:Exit
  endlocal
```

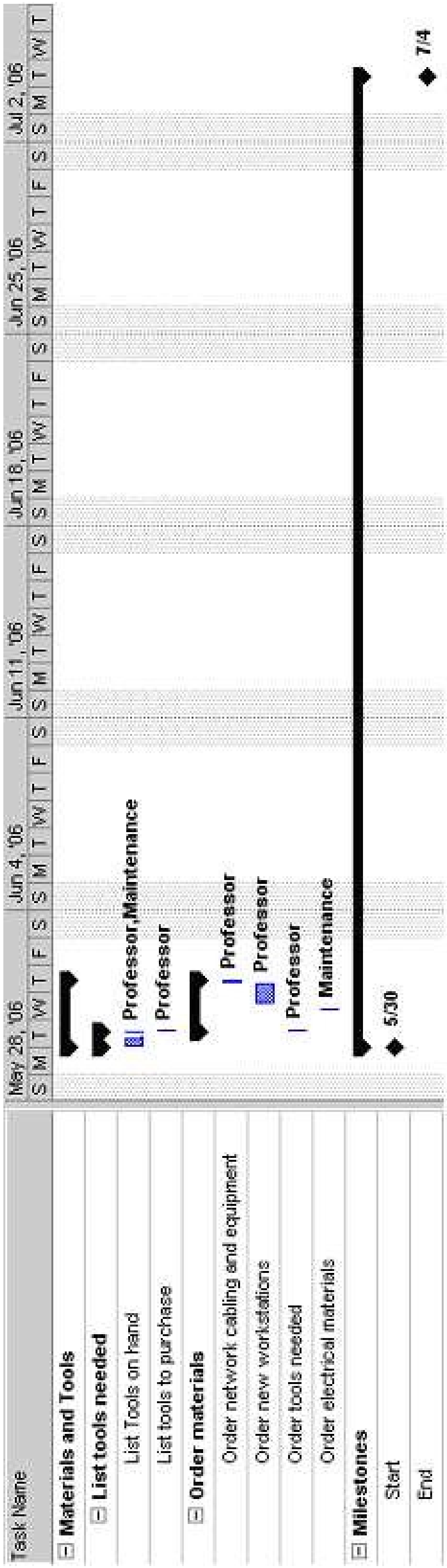
Appendix B – Gantt Chart




Task Name
Install/Configure Servers
Have IT Department build servers to specifications
Install Servers in central server cabinet
Install Windows 2003 Server OS
Install and tweak OS
Turn off unnecessary services
Configure infrastructure services
Active Directory
Install Active Directory
Create OU Structure
Create users, groups, and computers
Create and configure Group Policy objects
DNS
Install DNS
Create and configure forward zones
Create and configure reverse zones
Configure DNS Forwarding
DHCP
Configure and activate DHCP Scope for RIS clients
RIS
Configure RIS with Windows XP Volume License version
Apply unattended answer files to images
WSUS
Install WSUS
Configure Update Synchronization
Configure update policy
Add workstations to WSUS groups
MBSA
Install MBSA
Configure MBSA to synchronize with WSUS
Scan servers and workstations
Jun 4, '06
Jun 11, '06
Jun 18, '06
Jun 25, '06
Jul 2, '06
Professor
Student

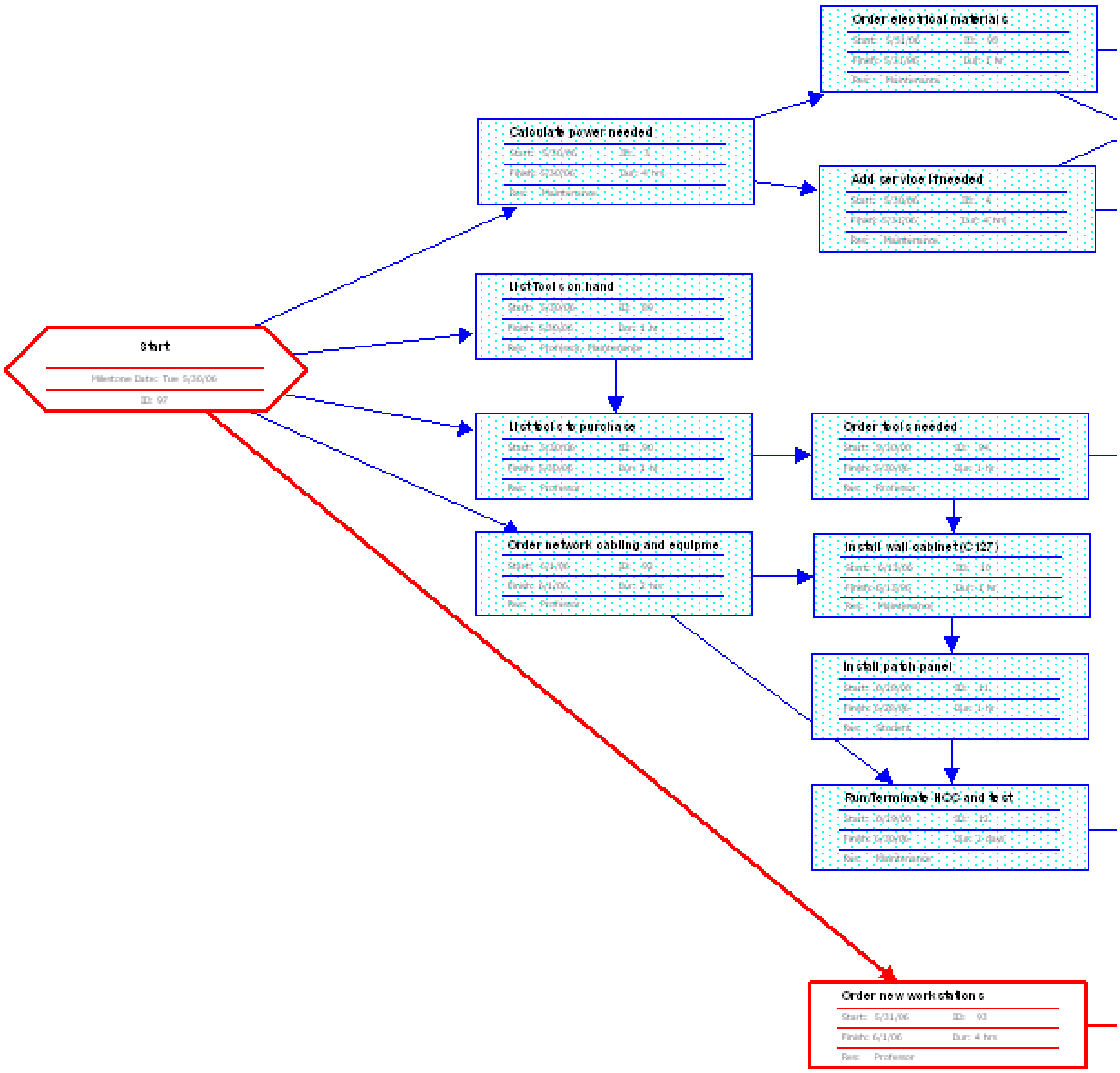


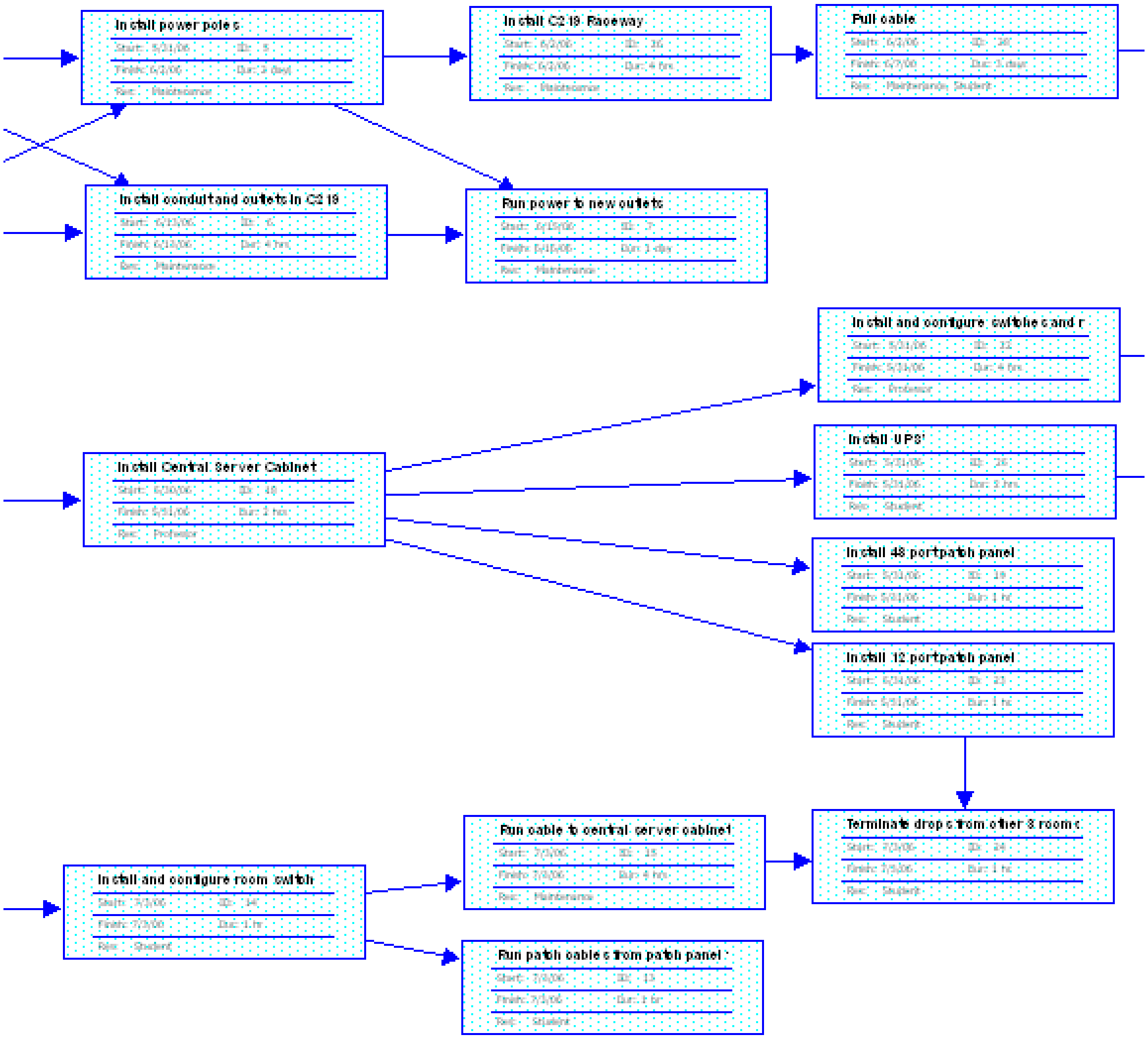
Task Name
File and Print Sharing
File Sharing
Create folders to share
Apply NTFS permissions
Share folders
Print Sharing
Install printers on server
Share printers
Apply Windows XP print drivers
Install/Configure Workstations
Set up new class rooms
Install desks in new rooms
Run power strips in new rooms
Physically install workstations
Install/cable student workstations in new rooms
Install/cable instructor workstation
Collect UUID numbers
Build image
Install Windows XP from RIS on each type of computer
Tweak Windows XP
Install and configure software
Upload image to RIS server
Create unattended answer file
Deploy image
Apply security settings
Jun 11, '06
Jun 18, '06
Jun 25, '06
Jul 2, '06
Jul 9, '06
Student
Professor,Student,Maintenance
Professor,Student

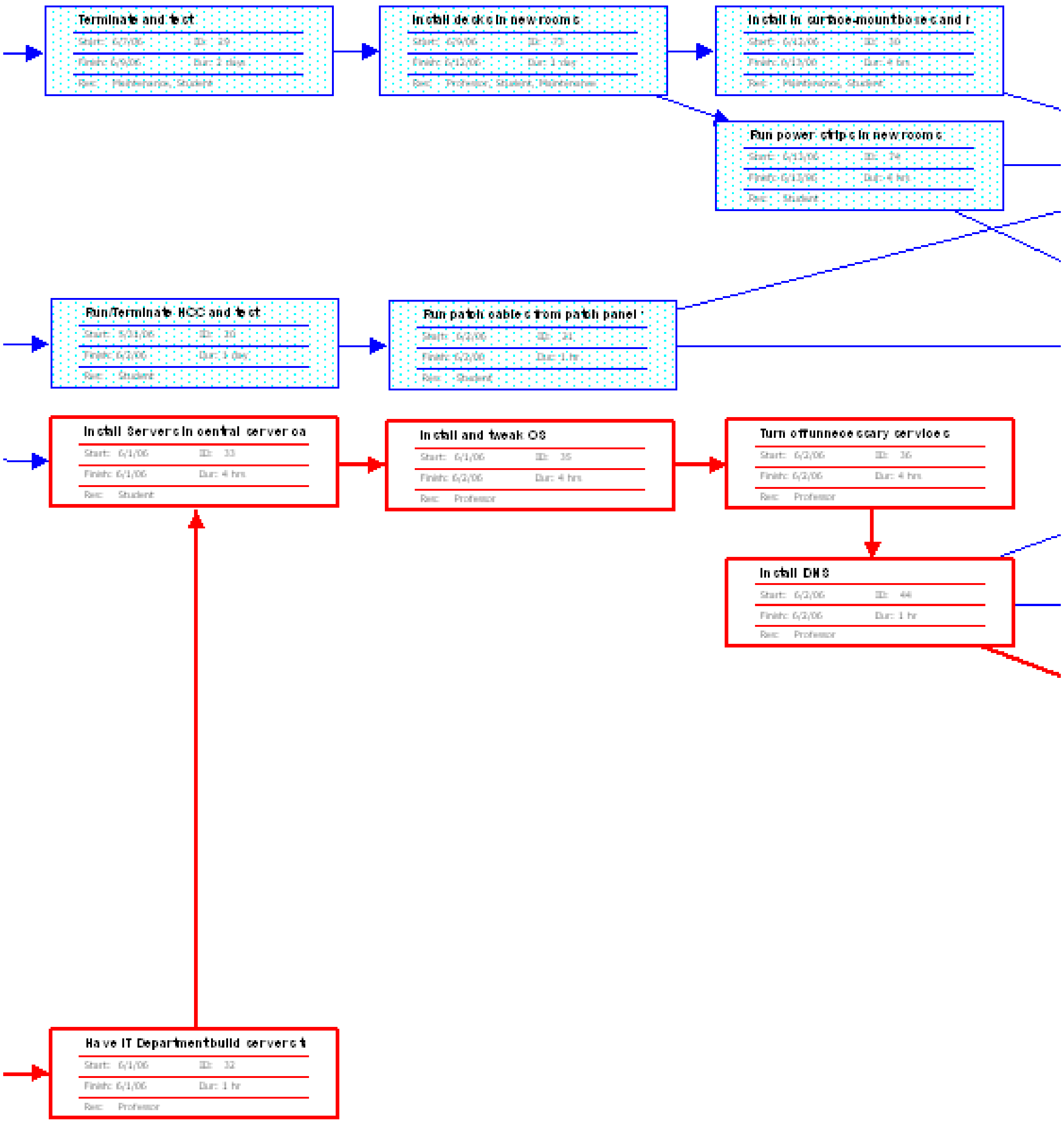


Task Name
Materials and Tools
List tools needed
List Tools on hand
List tools to purchase
Order materials
Order network cabling and equipment
Order new workstations
Order tools needed
Order electrical materials
Milestones
Start
End
May 28, '06
Jun 4, '06
Jun 11, '06
Jun 18, '06
Jun 25, '06
Jul 2, '06
S M T W T F S
Professor,Maintenance
Professor
Professor
Professor
Professor
Maintenance
5/30
7/4

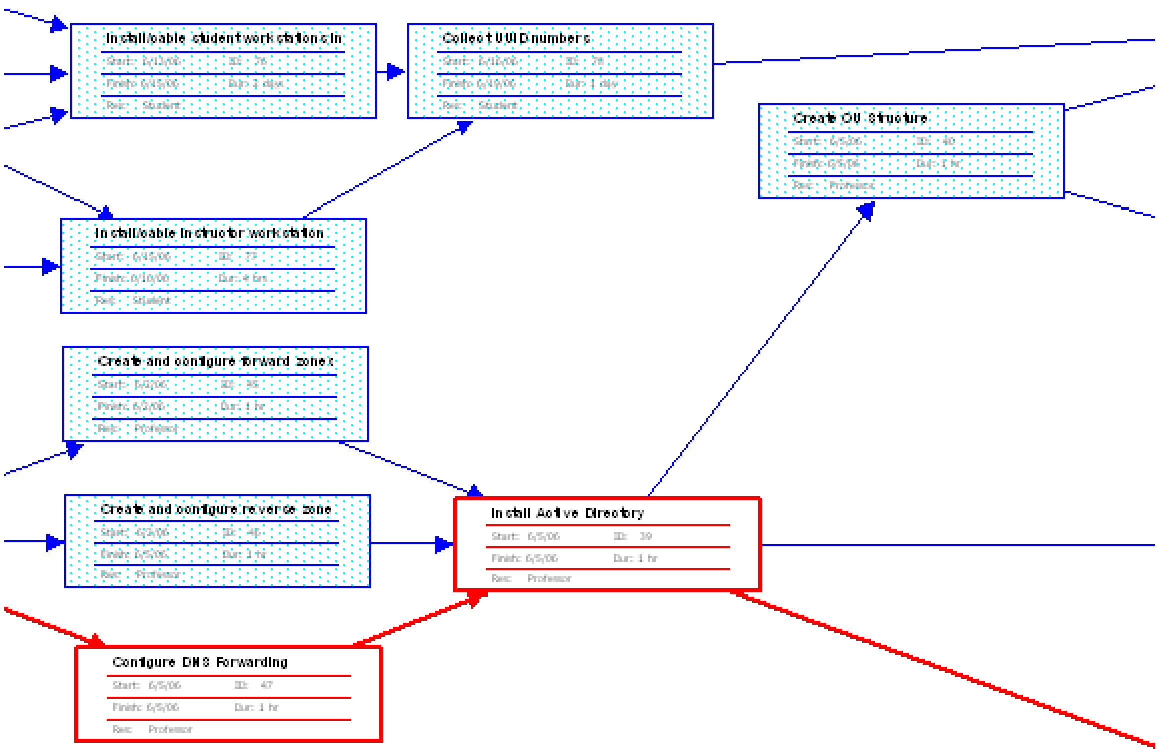
Appendix C – Network Diagram of Project

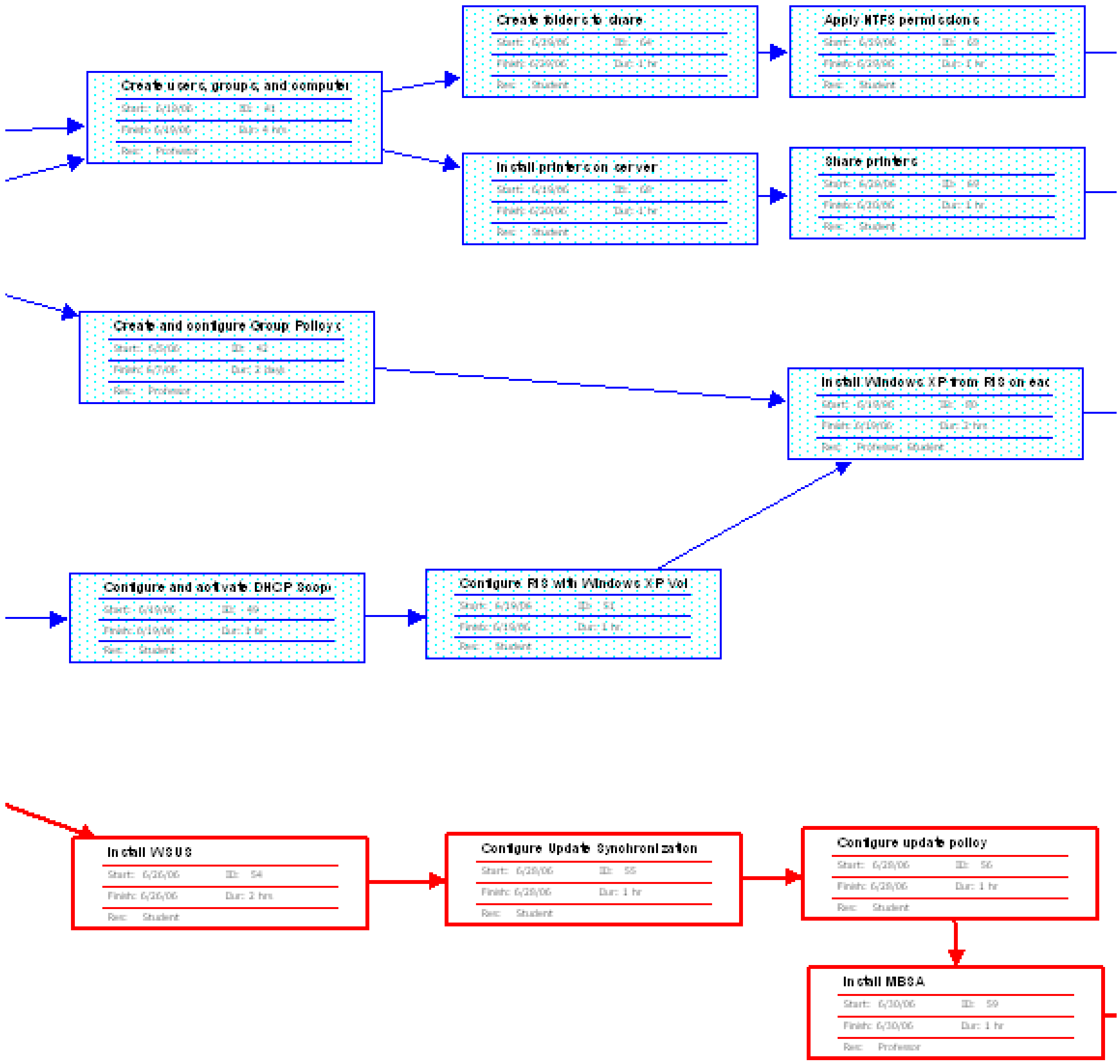



Install power poles
Install C219 Raceway
Pull cable
Install conduit and outlets in C219
Run power to new outlets
Install and configure switches and r
Install UPS'
Install Central Server Cabinet
Install 48 port patch panel
Install 12 port patch panel
Run cable to central server cabinet
Terminate drops from other 3 rooms
Install and configure room switch
Run patch cables from patch panel

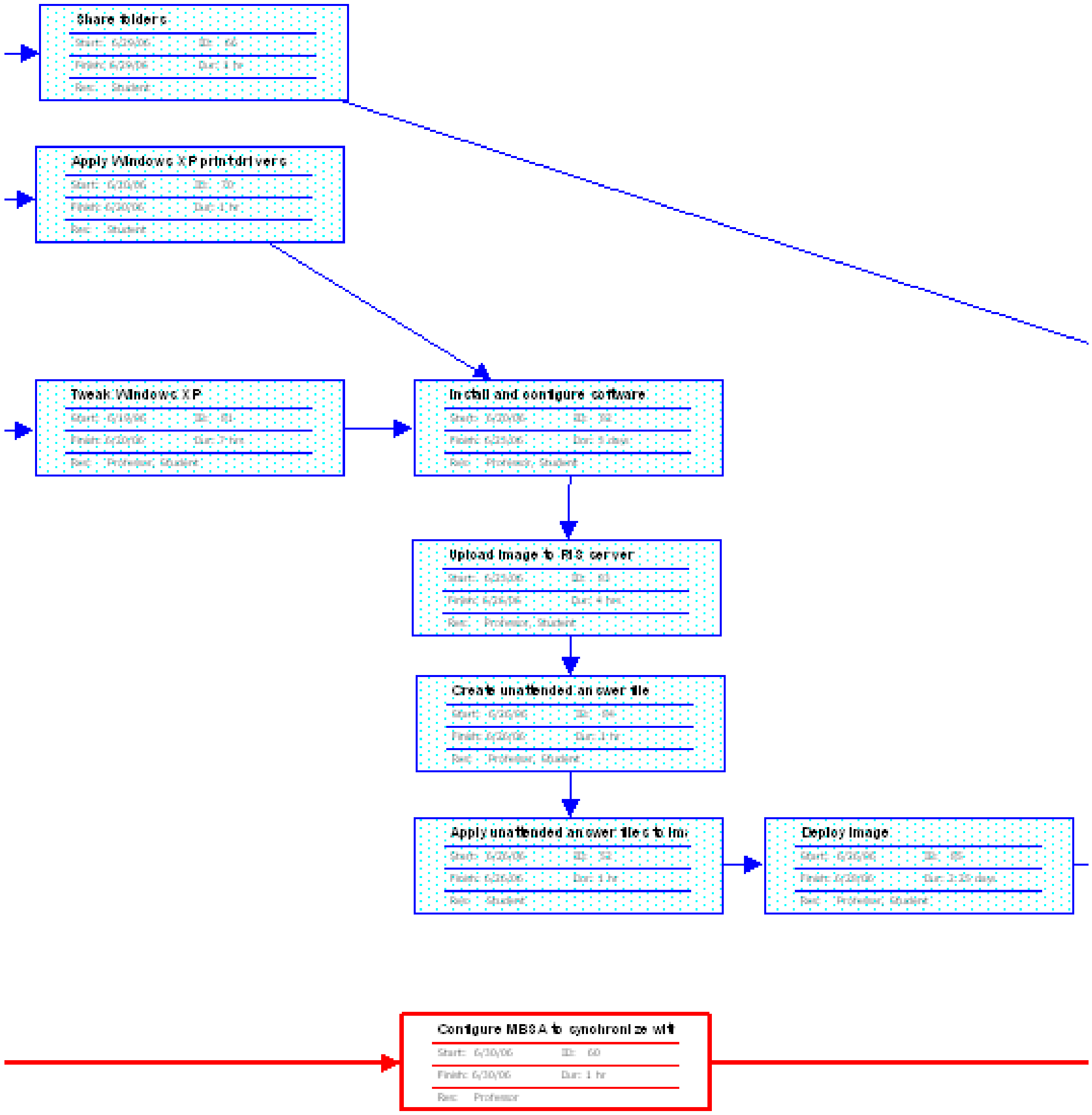


Terminate and test
Install decks in new rooms
Install in surface-mount boxes and r
Run power strips in new rooms
Run/Terminate HCC and test
Run patch cables from patch panel
Install Servers in central server oa
Start: 6/1/06 ID: 33
Finish: 6/1/06 Dur: 4 hrs
Res: Student
Install and tweak OS
Start: 6/1/06 ID: 35
Finish: 6/2/06 Dur: 4 hrs
Res: Professor
Turn off unnecessary services
Start: 6/2/06 ID: 36
Finish: 6/2/06 Dur: 4 hrs
Res: Professor
Install DNS
Start: 6/2/06 ID: 44
Finish: 6/2/06 Dur: 1 hr
Res: Professor
Have IT Department build servers t
Start: 6/1/06 ID: 32
Finish: 6/1/06 Dur: 1 hr
Res: Professor

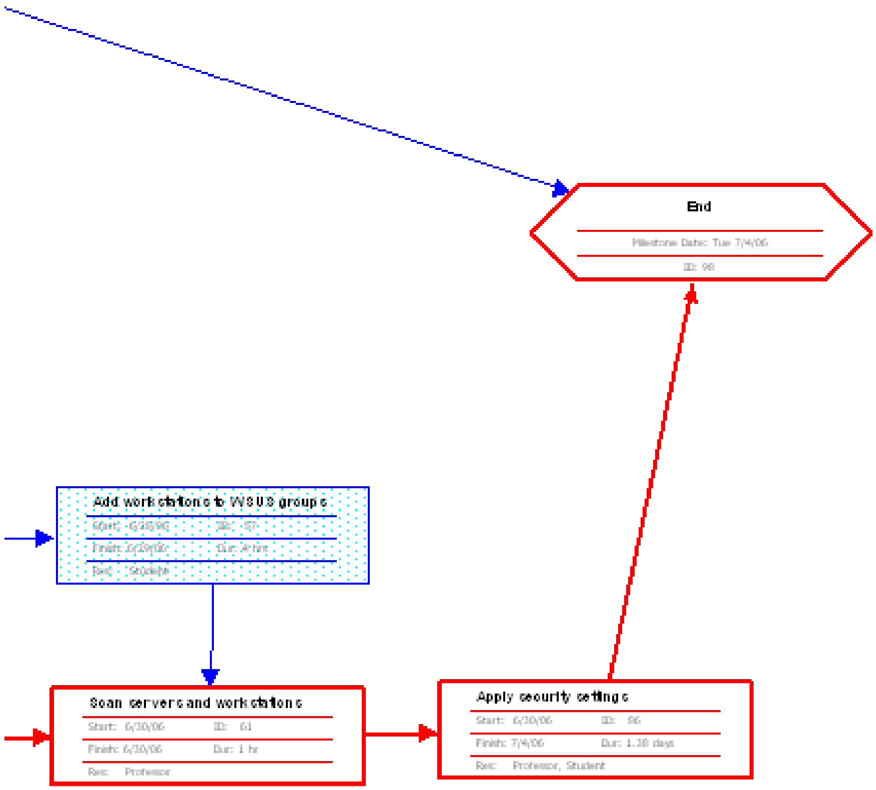

Install/cable student workstations in
Collect UUID numbers
Create OU Structure
Install/cable instructor workstation
Create and configure forward zones
Create and configure reverse zone
Install Active Directory
Start: 6/5/06
ID: 39
Finish: 6/5/06
Dur: 1 hr
Res: Professor
Configure DNS Forwarding
Start: 6/5/06
ID: 47
Finish: 6/5/06
Dur: 1 hr
Res: Professor



Create users, groups, and computer
Create folders to share
Apply NTFS permissions
Install printers on server
Share printers
Create and configure Group Policy
Install Windows XP from RIS on eac
Configure and activate DHCP Scope
Configure RIS with Windows XP Vol
Install WSUS
Start: 6/26/06
ID: 54
Finish: 6/26/06
Dur: 2 hrs
Rec: Student
Configure Update Synchronization
Start: 6/28/06
ID: 55
Finish: 6/28/06
Dur: 1 hr
Rec: Student
Configure update policy
Start: 6/28/06
ID: 56
Finish: 6/28/06
Dur: 1 hr
Rec: Student
Install MBSA
Start: 6/30/06
ID: 59
Finish: 6/30/06
Dur: 1 hr
Rec: Professor



Share folders
Start: 6/29/06
ID: 66
Finish: 6/29/06
Dur: 1 hr
Res: Student
Apply Windows XP printdrivers
Tweak Windows XP
Install and configure software
Upload Image to RIS server
Create unattended answer file
Apply unattended answer files to im
Deploy Image
Configure MBSA to synchronize wit
Start: 6/30/06
ID: 60
Finish: 6/30/06
Dur: 1 hr
Res: Professor


End
Milestone Date: Tue 7/4/06
ID: 90
Add workstations to WSUS groups
Scan servers and workstations
Start: 6/30/06
ID: 61
Finish: 6/30/06
Dur: 1 hr
Res: Professor
Apply security settings
Start: 6/30/06
ID: 86
Finish: 7/4/06
Dur: 1.38 days
Res: Professor, Student

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