WHITE PAPER

December 1998

Prepared By
Workstation Marketing Services

Compaq Computer Corporation

Contents

Accelerating Financial Spreadsheet Simulations with Workstation Clusters

Abstract: *Finance related industries have long used sophisticated modeling and simulation to predict trends and outcomes, and used these simulations to guide decisions and investments. These approaches are used for pricing, analysis, risk management, allocation and hedging of equity, fixed income, foreign exchange, derivatives, commodity, and mortgage backed security instruments. Being able to more accurately simulate probable outcomes of complex real-world activities is critical to the survival and success of many companies today.*

Traditionally, programmers have developed proprietary applications that were used by the quantitative (aka "quants") financial experts – often as special purpose "black box" systems. Historically these applications have been hosted on large UNIX/RISC workstation clusters or on large multi-processor UNIX/RISC servers. A recent development is to use high level tools – most notably spreadsheets – to develop the models and run the simulations.

This paper explores the use of spreadsheet technology, extensions to spreadsheets to support simulation, and distributed computational engines ("workstation clusters") to provide a high-performance environment for business simulation.

COMPAQ

ECG054/1298

NOTICE

The information in this publication is subject to change without notice and is provided "AS IS" WITHOUT WARRANTY OF ANY KIND. THE ENTIRE RISK ARISING OUT OF THE USE OF THIS INFORMATION REMAINS WITH RECIPIENT. IN NO EVENT SHALL COMPAQ BE LIABLE FOR ANY DIRECT, CONSEQUENTIAL, INCIDENTAL, SPECIAL, PUNITIVE, OR OTHER DAMAGES WHATSOEVER (INCLUDING WITHOUT LIMITATION, DAMAGES FOR LOSS OF BUSINESS PROFITS, BUSINESS INTERRUPTION OR LOSS OF BUSINESS INFORMATION), EVEN IF COMPAQ HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

The limited warranties for Compaq products are exclusively set forth in the documentation accompanying such products. Nothing herein should be construed as constituting a further or additional warranty.

This publication does not constitute an endorsement of the product or products that were tested. The configuration or configurations tested or described may or may not be the only available solution. This test is not a determination of product quality or correctness, nor does it ensure compliance with any federal state or local requirements.

Microsoft, Windows, and Windows NT are trademarks and/or registered trademarks of Microsoft Corporation.

Intel and Pentium are trademarks and/or registered trademarks of Intel Corporation.

Product names mentioned herein may be trademarks and/or registered trademarks of their respective companies.

© 1998 Compaq Computer Corporation. All rights reserved. Printed in the U.S.A.

Accelerating Financial Spreadsheet Simulations with Workstation Clusters

December 1998

ECG054/1298

Introduction

Finance related industries have long used sophisticated modeling and simulation to predict trends and outcomes, and used these simulations to guide decisions and investments. These approaches are used for pricing, analysis, risk management, allocation and hedging of equity, fixed income, foreign exchange, derivatives, commodity, and mortgage backed security instruments. Being able to more accurately simulate probable outcomes of complex real-world activities is critical to the survival and success of many companies today.

Traditionally, programmers have developed proprietary applications that were used by the quantitative (aka "quants") financial experts – often as special purpose "black box" systems. Historically these applications have been hosted on large UNIX/RISC workstation clusters or on large multi-processor UNIX/RISC servers. A recent development is to use high level tools – most notably spreadsheets – to develop the models and run the simulations.

Spreadsheets have the advantages of being easy and intuitive for non-programmers to develop and use. They are flexible and can be readily modified and extended. Today's spreadsheets, especially Microsoft ®Excel, provide powerful modeling and analysis tools.

One characteristic of spreadsheets is that they are *analytical tools* – they provide exact solutions to a problem. In many cases, this is appropriate. A weakness of spreadsheets is that they insist on providing a single exact solution – they are not designed to provide a range of possible outcomes to a range of possible inputs. They are not intended to work directly with input variables subject to uncertainty or to forecast probabilistic outcomes. A financially relevant example would be a simulation that could forecast the impacts of a range of inflation, interest, and foreign exchange rates.

Spreadsheets are commonly used in "what if" analysis. A spreadsheet is built that incorporates all assumptions and then evaluated. The assumptions are then changed, and the spreadsheet is re-evaluated. This process is repeated as many times as necessary. While the "what if" is a valuable tool, it has a number of drawbacks. Each set of changes to the assumptions must be manually input, the results must be manually recorded, and it is difficult to readily determine probabilities and sensitivities to changes in various input variables.

The simulation capabilities of spreadsheets have been extended with Microsoft Excel add-ins, such as Crystal Ball® from Decisioneering. Crystal Ball extends Microsoft Excel to support Monte Carlo simulation – a powerful and widely used methodology for simulation. Monte Carlo methods enable using the solution to a specific problem to solve a more general problem.

While the use of spreadsheets and Monte Carlo simulation provides an exceptionally powerful and flexible environment, it can also produce long run times. Customers have reported that complex, sophisticated models can require 20 hours or longer to analyze. While this is a great improvement over not being able to run a simulation at all, it is a major limitation in many time sensitive financial environments.

A familiar approach in the computing world, when a single system is too slow, is to apply multiple systems to the problem – to run parts of the problem in parallel with each other, and thus reduce the elapsed time required to solve the problem. A workstation clustering approach is presented here as a solution to the Monte Carlo run time problem.

Spreadsheet Clusters

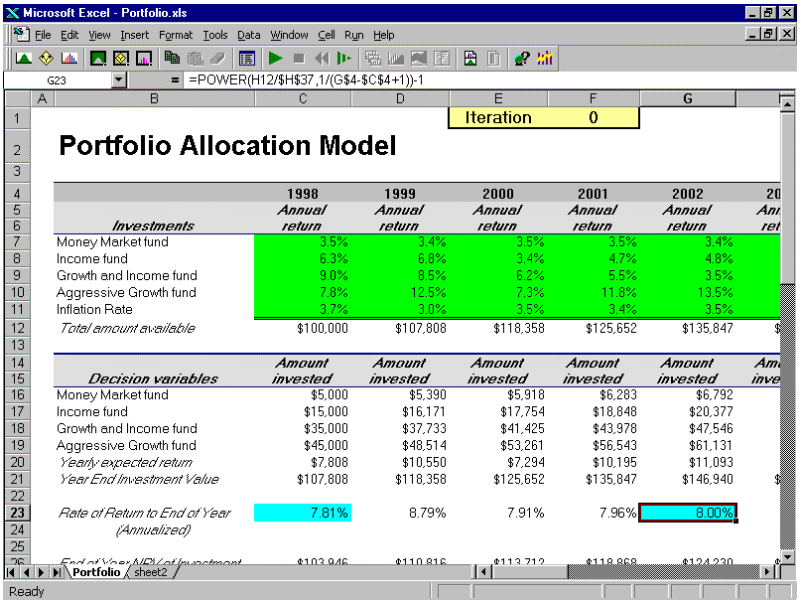
Spreadsheet clusters provide a high performance Microsoft Excel-based simulation environment for financial modeling. In fact this solution is unique to Microsoft Windows NT ® Intel ® processor-based workstation clusters and cannot be provided by UNIX/RISC systems due to the lack of Microsoft Excel ports or the reduced performance of software emulators compared to the native Intel instruction set implementations. There are several components to a Spreadsheet cluster, which is a workstation cluster built using Compaq Professional Workstations, Microsoft Excel, Crystal Ball Turbo™ from Decisioneering and Paradise® from Scientific Computing Associates. With these pieces, the elapsed time for an individual user's Microsoft Excel simulation models is dramatically accelerated compared to runs made on a single processor system.

Additionally, large Crystal Ball Turbo cluster configurations can provide an execution engine that can be shared by multiple users, delivering speedy answers to a group rather than just a single person. Since these clusters are based on standard components – both hardware and software – they are fast, cost effective and easily expandable.

Microsoft Excel

Microsoft Excel is a powerful, flexible spreadsheet with a comprehensive set of features and functions. It is widely used for a broad range of tasks, from simple daily activities to complex, sophisticated simulation models.

Microsoft Excel has two features that are especially significant for financial modeling: first, it has excellent connectivity and communication abilities. This allows Microsoft Excel spreadsheets to work with external connections and respond to changing in real-time data. Second, the Microsoft Excel architecture allows new functions to be added by outside developers. This allows special functions to be developed, added to the spreadsheet environment, and used exactly like native Microsoft Excel functions are used.



Example Microsoft Excel-based Financial Model with CB Turbo Add-in

Crystal Ball Products from Decisioneering

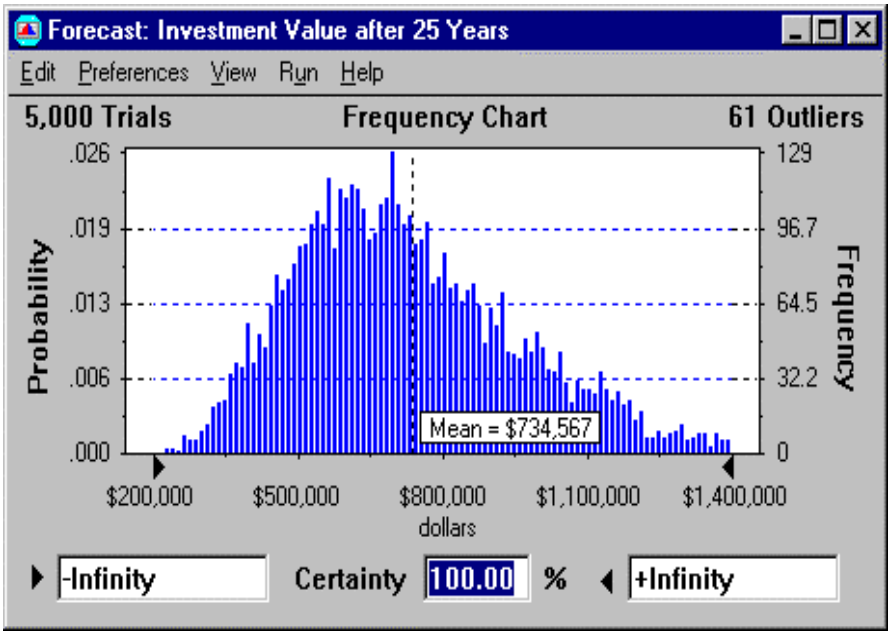
Crystal Ball is a Microsoft Excel spreadsheet add-in that is widely used in risk analysis and forecasting applications within large corporations across many industries. Crystal Ball allows analysts to easily vary input data and to determine the probability that their forecasts will be accurate. The analysts input their assumptions as well as information on how they expect each assumption to statistically vary. A wide range of choices for variation may be used, ranging from random numbers, to a variety of probability distribution curves to the use of historical data.

When the spreadsheet is evaluated, it looks at various outcomes based on randomly generated figures for each variable. Depending on how closely you look, the spreadsheet may be evaluated a thousand times, ten thousand times, or more.

The results are typically displayed in a graphical format, providing enhanced understanding. Depending on the desired results, you might be interested in the median value, the mean value, the value with 50% probability of happening, or a high probability result. For example, when analyzing the expected result of an investment of $100,000, you might discover that there is a 50% probability of achieving a return of $200,000, and a 90% probability of achieving a return of $110,000 or greater.

Since many investments do not have a guaranteed return, it is critical to understand the possible range of returns and the probability of each return. Knowing the probability of a return doesn't guarantee the return, but knowledge of likelihood is a powerful decision making tool.

Crystal Ball handles dozens of assumptions simultaneously, and supports correlation coefficients among variables. For example, when doing retirement planning, you might assume that as annual rate of return on investments increases, the length of time to retirement date decreases – this would imply that when someone sees their nest egg growing faster than anticipated, they are more likely to retire earlier.



Results of CB Turbo Portfolio Allocation Simulation

While Crystal Ball provides powerful tools for simulation and analysis, it can take a lot of time to run a thousand – or ten thousand! – iterations of a complex model. Crystal Ball Turbo extends Crystal Ball by allowing a single job to easily run in parallel across a number of systems. By applying multiple processors to a single job, it is possible to speed up a simulation by a factor of ten times, twenty times, or even more.

Crystal Ball Turbo is fully compatible with Crystal Ball. Spreadsheets can be developed with Crystal Ball, and then run with Crystal Ball Turbo. Furthermore, existing Microsoft Excel spreadsheets that customers use in a manual Monte Carlo simulation process, can be easily incorporated.

Crystal Ball Turbo supports distribution of a simulation job, dynamic reassignment of systems used in a simulation, and fault tolerance by compensating for system failures during a simulation run. It can be run in a dedicated environment (such as a rack-mounted cluster), can utilize existing systems within a local area network, and can even utilize systems spread across a wide area network.

Paradise Products from Scientific Computing Associates

Paradise from Scientific Computing Associates is a flexible and powerful distributed computing environment. Paradise is derived from Scientific's Linda® product, which has been used for years in development of proprietary financial codes and throughout the scientific/engineering computing segment. Paradise can be used to create "ensemble applications" from separate, independent programs. For example, data from a server-based database application might be placed into Paradise's Virtual Shared Memory (VSM) either as it is collected or on a periodic basis. A separate analysis application would execute simulations based on this data, with the analysis application running on a single system or distributed across a number of systems for parallel processing.

Paradise provides the tools for starting, distributing, managing, synchronizing and terminating tasks across a distributed computing environment. These tools are used to execute "tasks," which are pieces of an application that can be run in parallel. In many cases, a task will be a complete application, running with a specific set of input data. In fact, it is Paradise that enables Crystal Ball Turbo jobs to run in parallel across a workstation cluster.

Paradise allows existing programs to be easily and quickly connected. With only minimal modifications, completely independent programs can share data.

Paradise includes a sophisticated fault-tolerance facility that allows programs to guarantee data integrity despite hardware failures, abnormal process termination, lost connections between computers, and other failures. It is structured around a begin-commit transaction strategy similar to that used in state-of-the-art database systems. Changes ("atomic transactions" in database terminology) to a VSM are not made permanent until they are committed by the application performing them, and uncommitted transactions are cancelled in the event of failures.

One other unique Scientific product is Piranha®. This product allows parallel applications to take advantage of idle processors on workstations distributed throughout the network. For instance, CB Turbo can start jobs on a system once the screen saver becomes active (other idleness metrics are possible too). Piranha will also migrate the simulation to another system once the user returns for an interactive session.

Compaq Workstation Clusters

Workstation Clusters are a proven technique to allow the power of multiple workstations to be applied to solving a single problem. They reduce the time required to solve a problem, thus allowing more runs to be made in a given amount of time, or allowing people to act on the results of an analysis more quickly. In the case of a financial simulation, for example, reducing the run time from 20 hours to an hour allows responding to market changes several times in a single day, rather that being forced to wait until *tomorrow* to respond to *this morning's* trends.

Workstation clusters consist of several pieces. First are the high performance computational nodes, which are based on workstations. Second is the high performance communications between these computational nodes, which allows them to work cooperatively. And, last but certainly not least, is the software running in the cluster environment. This software both performs the simulation and distributes and synchronizes the individual computational nodes that are performing various parts of the simulation.

Compaq Professional Workstations provide the ideal platform for building workstation clusters. Their combination of high performance, integrated high speed networking, rack mountable enclosures, and support for key software technologies combine to deliver a powerful solution to spreadsheet-based Monte Carlo simulation.

Compaq Professional Workstation Cluster Components

Several components make up a workstation cluster: workstations, interconnect, and software are the major pieces. The physical workstations may be either distributed or consolidated in a rack. Because the focus of this paper is on building a dedicated application acceleration system, we will address rack mount clusters.

Compaq Professional Workstation AP500

The Compaq Professional Workstation AP500 is based on the Intel Pentium ®II processor and supports single or dual processors. When used in a workstation cluster, it is recommended that it be configured with two processors and at least 256 MB of memory. The AP500 uses the Intel 440BX core logic chipset, which supports a 100 MHz system (or “frontside”) bus.

Integrated into the workstation is a 10/100 Mb/sec Ethernet controller. This controller uses a full 32 bit PCI interface, providing optimal performance while placing minimal load on the host system.

The standard AP500 workstation is packaged in a tower configuration. This package also supports a rackmount kit, enabling the AP500 to be mounted in a standard 19” rack. A typical workstation cluster configuration will include 4-8 AP500 workstations mounted in a rack.

Racks and Accessories

There are several advantages to rack mounting systems. First, it gets the greatest amount of computational resources into the smallest floor space – a significant advantage in both computer rooms and in office environments. It provides greater integration, and eases cabling for power sources, networking, and system monitoring. Customers also highly value the ability to initially rack-mount a new workstation that represents the latest technology and then later redeploy it as a deskside system dedicated to a single user.

A rack mounted system can be configured with an integral UPS (Uninterruptible Power Supply), providing protection from power problems and outages. A rack mount system also provides a cleaner installation, in that all of the connections between the workstations are contained within the rack.

The AP500 has an optional rack-mounting kit, which allows efficient integration into the Compaq Rack 4000 and Rack 7000 Series.

Compaq has a full suite of rack-mount accessories to complement a workstation cluster configuration including:

- Fold down flat panel monitors
- Keyboard / monitor / mouse switches
- Drawers and pedestals
- Power distribution units and Uninterruptible Power Supplies
- RAID disk arrays
- Keyboards with trackballs
- Cable management kits
- Bolt together kits (multiple racks)

Rack Mounted Compaq Professional Workstations

100 Mb/sec Switched Ethernet

Communication between the workstation nodes is a key component in workstation clusters. The AP500 includes as a standard component a high performance 10/100 Mb/sec Ethernet controller or "NIC" (Network Interface Controller). This NIC is integrated onto the system board of the AP500 workstation. Workstation clusters normally use 100 Mb/sec Ethernet and the communication protocol is standard TCP/IP.

In an ordinary Ethernet hub-based environment, all systems share the 100 Mb/sec bandwidth of the Ethernet. A crossbar switch, such as the Compaq Netelligent 5708 TX, extends this by providing a direct connection between each *pair* of communicating systems. The result is that the aggregate bandwidth is increased to 100 Mb/sec times one-half the number of nodes. This number is arrived at quite simply – each *pair* of systems can communicate with each other at the full Ethernet bandwidth. Thus, there is 100 Mb/sec of bandwidth between each pair of systems talking to each other. For example, four workstation nodes connected through an Ethernet switch would have 200 Mb/sec of communication bandwidth, and eight nodes would have 400 Mb/sec of total communication bandwidth.

Remote Management

System management is always an important issue for critical systems. With dedicated workstation clusters, it is even more important. Compaq Professional Workstation clusters are optimized to deliver this management for high-performance business and design applications in a Windows NT environment. Each Compaq Professional Workstation has Windows NT Workstation preinstalled for easier installation and management of the workstation cluster.

Compaq Insight Manager constantly monitors and analyzes critical information for every Compaq Professional Workstation in the cluster, as well as other supported systems. More importantly, it brings that information right to you wherever you are, and gives you the tools to respond from a management console or Web browser. So you can quickly and easily address issues before they become a problem - preventing downtime and costly data loss while saving you time and legwork.

Windows NT is a high-performance, highly reliable, secure multithreaded operating system. It provides maximum 32-bit performance that meets the needs of demanding applications. For simplified file storage and data sharing, Windows NT interoperates with other Compaq systems and with existing corporate networks by providing support for multiple network protocols. The Compaq Professional Workstation cluster includes an extensive set of system management tools, such as Windows NT's Performance Monitor and Compaq Insight Manager.

CB Turbo Cluster Successes

Compaq customer Enron Capital & Trade Resources Corporation runs CB Turbo in production within their energy trading environment. CB Turbo is used to project the impact of uncertainty in inflation, interest rates, exchange rates, etc. A separate more detailed success story is available on this deployment (see the Compaq Web site at www.compaq.com/solutions/stories/enron.html).

Several securities firms are currently planning CB Turbo deployments on Compaq Professional Workstation Clusters. Compaq and its partners recently worked with one institution to reduce the run time for a derivatives model by 40 times compared to the uniprocessor workstation they were using. The customer's existing Microsoft Excel spreadsheet, previously used in a manual Monte Carlo simulation process, was modified to work with CB Turbo to scale across 50 processors (25 dual processor workstations). Due to these excellent results, this firm has decided to standardize on Compaq Professional Workstation Clusters and CB Turbo to solve its Microsoft Excel-based Monte Carlo simulations.

More Information

Compaq Professional Workstation Clusters

Compaq Computer Corporation
P.O. Box 692000
Houston, Texas 77269-2000

Phone: 281.370.0670
Fax: 281.514.1740

http://www.compaq.com/products/workstations

Crystal Ball, Crystal Ball Pro, Crystal Ball Turbo

Decisioneering
1515 Arapahoe Street
Suite 1311
Denver, CO 80202

Phone: 800.289.2550 (in US) 303.534.1515
Fax: 303.534.4818
Email: sales@decisioneering.com

http://www.decisioneering.com

Paradise and Piranha

Scientific Computing Associates
One Century Tower
265 Church Street
New Haven, CT 06510 USA

Phone: (203)777-7442
Fax: (203)776-4074
Email: software@sca.com

http://www.sca.com

Microsoft Excel

Microsoft
One Microsoft Way
Redmond, WA 98052-6399
Telephone: (425) 882-8080

http://www.microsoft.com

Sample Cluster Configurations

These configurations are provided as examples of how various size clusters can be configured using Compaq Professional Workstations. Detailed cluster configurations should be validated to ensure that all required components for each specific installation are included.

Configuration #1

AP500 42U Rack cluster (7 workstations, 14 processors, 512 MB memory each, extra 9GB hard drive each)

Qty.	Part Number	Description
7	338544-B21	AP500 Rack-mount Kit
1	332662-001	Rackmount Flat Panel Monitor
7	165638-001	CPU-to-Switch Box Cable, 9'
1	167050-001	Netelligent 5708 8 port, 100Mbps Ethernet Switch
1	169989-001	Keyboard / Monitor Extension Cable
1	242695-001	Keyboard/Monitor/Mouse Switch Box (8 port)
3	295363-002	Power Distribution Unit (220V Model)
1	303607-B21	Keyboard Drawer
1	185152-001	Trackball Keyboard
1	165753-001	Rack Model 7142
1	165652-001	Sidewall Panel Kit for Rack 7142
1	189907-001	Stabilizing Feet for Rack 7142
1	169940-001	Blanking Panel Kit
1	347275-001	Side-mounting bracket for K/M/M Switch
7	121565-002	High Voltage AP500 Power Cords
7	338500-005	AP500 – 450 MHz, 128MB, 2D, 4G
7	354479-B21	450 MHz Pentium II processor
21	317738-B21	128MB DIMM
7	336369-B21	9.1 GB / 10K rpm hard drive
7	329294-B21	10K rpm disk cooling kit

Configuration #2		
AP500 22U Rack cluster (4 workstations, 8 processors, 256 MB memory each)		
Qty.	**Part Number**	**Description**
4	338544-B21	AP500 Rack-mount Kit
1	285006-001	TFT500 Flat Panel Monitor (External)
4	165638-001	CPU-to-Switch Box Cable, 9'
1	167050-001	Netelligent 5708 8 port, 100Mbps Ethernet Switch
1	169989-001	Keyboard / Monitor Extension Cable
1	242694-001	Keyboard/Monitor/Mouse Switch Box (4 port)
2	295363-002	Power Distribution Unit (220V Model)
1	303607-B21	Keyboard Drawer
1	185152-001	Trackball Keyboard
1	163747-001	Rack Model 7122
1	347275-001	Side-mounting bracket for K/M/M Switch
4	121565-002	High Voltage AP500 Power Cords
1	169940-001	Blanking Panel Kit
4	338500-005	AP500 - 450MHz, 128MB, 2D, 4G
4	354479-B21	450 MHz Pentium II processor
4	317738-B21	128MB DIMM

Configuration #3

AP500 42U Rack cluster (28 workstations, 56 processors, 512 MB memory each, extra 9GB hard drive each)

1st Rack :

Qty.	Part #	Description
7	338544-B21	AP500 Rack-mount Kit
1	332662-001	Rackmount Flat Panel Monitor
7	165638-001	CPU-to-Switch Box Cable, 9'
1	167050-001	Netelligent 5708 8 port, 100Mbps Ethernet Switch
1	273850-001	Netelligent 5606 6 port, 100Mbps Ethernet Switch
2	169989-001	Keyboard / Monitor Extension Cable
2	242695-001	Keyboard/Monitor/Mouse Switch Box (8 port)
3	295363-002	Power Distribution Unit (220V Model)
1	303607-B21	Keyboard Drawer
1	185152-001	Trackball Keyboard
1	165753-001	Rack Model 7142
1	165652-001	Sidewall Panel Kit for Rack 7142
1	169940-001	Blanking Panel Kit
1	347275-001	Side-mounting bracket for K/M/M Switch
1	347275-002	Side-mounting bracket for K/M/M Switch
7	121565-002	High Voltage AP500 Power Cords
7	338500-005	AP500 - 450MHz, 128MB, 2D, 4G
7	354479-B21	450 MHz Pentium II processor
21	317738-B21	128MB DIMM
7	336369-B21	9.1 GB / 10K rpm hard drive
7	329294-B21	10K rpm disk cooling kit

Configuration #3 *continued*		
Racks 2 - 4 :		
7	338544-B21	AP500 Rack-mount Kit
7	165638-002	CPU-to-Switch Box Cable, 20'
1	167050-001	Netelligent 5708 8 port, 100Mbps Ethernet Switch
1	169989-001	Keyboard / Monitor Extension Cable
1	242695-001	Keyboard/Monitor/Mouse Switch Box (8 port)
3	295363-002	Power Distribution Unit (220V Model)
1	165753-001	Rack Model 7142
1	165664-001	Coupling Kit for Rack 7142
1	169940-001	Blanking Panel Kit
1	347275-001	Side-mounting bracket for K/M/M Switch
7	121565-002	High Voltage AP500 Power Cords
7	338500-005	AP500 - 450MHz, 128MB, 2D, 4G
7	354479-B21	450 MHz Pentium II processor
21	317738-B21	128MB DIMM
7	336369-B21	9.1 GB / 10K rpm hard drive
7	329294-B21	10K rpm drive cooling kit