COST EFFECT OF UNIQUELY DESIGNED COMPONENT CHOICES OVER THE PRODUCT LIFE OF A WORKSTATION

by

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B.S., Electrical Engineering, Suffolk University
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Submitted to the Department of Electrical Engineering and Computer Science
and to the Sloan School of Management
in Partial Fulfillment of the Requirements for the Degrees of

Master of Science in Electrical Engineering

and

Master of Science in Management

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ABSTRACT

A problem currently facing Hewlett-Packard Company's (HP) Computer Systems Organization is whether the workstation business at HP should be a value-add or commodity business as the personal computer and workstation businesses collide. Traditionally, the workstation business has found competitive advantage through its use of internally produced, unique components which optimize product performance due to component interplay. By taking as an example one recently released configuration of a low-range workstation product, material costs, infrastructure costs, and other costs that permeate the supply chain are examined to determine the impact of such choices on supply chain costs and break-even revenue.

Unlike many organizations where the component choices are driven from research and development, many of these choices are driven from marketing research. Thus, choices which seem to start out as a marketing "wish-lists" turn into choices which involve great cost impacts over the life of the product, and sometimes the life of the product family. By tracing the cost impact of internally designed components, especially where industry standard component choices could have been made, we can determine an estimate of the complete cost implications as opposed to material cost alone.

In this thesis, an analysis of the current cost per manufactured workstation, or cost per box, is first determined. Parameters affecting the cost of components where industry standard or platform leveraged components could be used but are not is then determined. A cost per box analysis is conducted to ascertain the projected percentage cost savings which would have been realized had the industry standard or platform leveraged commodity been used. Finally, a projected revenue break-even volume is determined for each of the scenarios analyzed. All data have been disguised to protect Hewlett-Packard Company.

The thesis is divided into four chapters. In the first chapter, the problem is introduced. In the second chapter, the modeling techniques used are presented. In the third chapter, various scenarios are presented, explained, and analyzed. In the fourth chapter, conclusions are given, as are recommendations for further study.

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I. INTRODUCTION

BACKGROUND

Hewlett-Packard Company (HP) currently manufactures workstations which, like all workstation manufacturers, are internally designed and unique to the OEM (Original Equipment Manufacturer). The research contained in this thesis was provided by the researching the workstation manufacturing in the United States, specifically in Exeter, New Hampshire, with Marketing and Development located in Chelmsford, Massachusetts and Fort Collins, Colorado. Additional background was obtained from HP's server manufacturing in Roseville, California, and corporate resources in Palo Alto, California.

Hewlett-Packard moved their U.S. based workstation manufacturing to Exeter, NH after acquiring Apollo Computer in 1990. A significant amount of work has been done in Exeter to optimize manufacturing processes. As a result, the actual final assembly and test of the workstation entails minimal direct labor and minimal direct cost. In tandem, much effort has been expended on optimization of their supply chain. Work in the supply chain optimization continues, as does in manufacturing, but the major impact difficulties in these areas have been solved and the more complex issues are now being studied. It became apparent to selected management at HP that the cost of materials and material holding is the next area where relatively low effort levels can reward the company with substantial cost reduction benefits.

The cost of components is increasingly important in the workstation industry, whereas it was not a major concern only a few years ago. When looking at the changing nature of the workstation industry, it is apparent that within the next three to four years, there will be significant shake-ups in the areas of standardized components, performance considerations, and margins which can be realized from workstation sales. Currently, unlike the personal computer industry, there is little which is common from one manufacturer to the next. There is no standardized processor, graphics platform, or operating system, though components such as hard drives, CD ROMs, monitors, and power supplies are extremely similar from one OEM to the next. The differences between these components from one manufacturer to the next could be simple such as different colored plastics or interconnects, or as complex as having all components except small chips unique from one manufacturer to the next. With the more complex items, similar structure and internal components may be seen from one manufacturer to the next, allowing the part to pass for industry standard. Since there is no true standard, we define "industry standard" as a component using standard technology with minimal tooling, development, and cost incurred by the supplier due to unique OEM design. When looking at Hewlett-Packard Company's workstation manufacturing business, there has been extensive work in the areas of manufacturing cycle time, delivery performance, supply chain maintenance, and, of course, component interconnect performance due to product design. The area which has been brushed aside during these other optimization efforts is material cost and an effort to use either industry standard components or components they currently are sourcing for other workstation designs.

STATEMENT OF THE PROBLEM

As more components move toward industry standard, HP must choose between a philosophy endorsing purchase of off-the-shelf, or industry standard, components or endorsing internally designed unique components. Currently, the rhetoric points toward procurement of industry standard components but the culture of the company leans toward uniquely designed parts. While this is fundamentally a make versus buy decision, the benefits and drawbacks of each choice are not well known. Considerable academic research has been conducted in the area of component sourcing decisions (Kumpe, et. al., 1988., Prahalad, et. al., 1990., Ulrich, 1993., Venkatesan, 1992., Welch, et. al., 1992., Whitney, 1988.). Literature supports the premise that a component should be designed and manufactured in-house if some characteristic of the component adds significant value to the company, or if the component performance or manufacturing processes offer the company a competitive advantage. In short, if designing and manufacturing a component adds competitive advantage, then part fabrication should be kept in-house, otherwise it should be outsourced. As Whitney emphasizes, though, there is no simple cost analysis way of looking the make versus buy decisions (Whitney, 1988). The decisions must be constantly reviewed and revised based on standards in the market and the competence of the OEM, as well as the suppliers.

There is a movement within the workstation industry, which is struggling to establish standards as to the components used within the workstation, the processor necessary to control the workstation, and software – both operating systems and applications. This push is driving down the price of the workstations, putting a squeeze on the 40% plus gross margins typical for the industry. As margins continue to shrink and as the performance of outside competitors, especially Sun Microsystems, Intel, and Microsoft, continues to increase rapidly, costs associated with workstation manufacturing will need to decline.

While a move toward industry standard components is necessary for maintaining its future competitive advantage, Hewlett-Packard faces a major challenge in altering the mindset of the development and marketing teams who define component choice. Unique components are designed such that the interconnect between all of the components improves, which in turn boosts the performance of the entire workstation system. The major drawback is cost. Added dollars in terms of development, material purchase price, and inventory holding, to name a few, beg the reader to ask whether the interconnect and component improvements truly boosts performance enough so that the average consumer is lured into purchasing this workstation. Also, it can be argued that similar performance can be achieved using industry standard components in an altered configuration.

A cost analysis case study was performed on HP's Apollo 260 low-end workstation from a materials point of view in order to capture the true cost which is added to the workstation over the life of the product due to using uniquely designed components. Below is a description of the project, the research methods and models used, results obtained, additional concerns which do not appear in the cost calculations, lessons learned, and recommendations. Areas investigated include material cost of the major sub-assemblies of the workstation, infrastructure necessary to support these components, supplier maintenance, inventory, development, manufacturing, quality and testing. The major sub-assemblies include monitors, mass storage, chassis / mechanical assembly, power supply, graphics cards, central processing unit, I/O interface cards, memory, hardware, labels / packaging, and cables / connectors.

Each of the major sub-assemblies was placed in one of three categories: unique internally designed components which are used solely in the Apollo 260 workstation (unique), uniquely designed components which are leveraged across the Apollo family of workstations and other families (platform leveraged), industry standard components based on the definition given earlier (industry standard). Note that if a component is industry standard and leveraged across multiple platforms, it is considered to be industry standard.

Various scenarios were developed by moving fewer than the maximum projected available components from uniquely designed to either industry standard or platform leveraged components. The expected goal of this analysis is to understand the cost / performance trade-off in workstation designs. In short, is the extra cost worth the increased performance or ease of design / manufacturability that was realized through the current component choice? In order to get a true benchmarking of the costs differences, development and marketing decisions were not considered. The main reason is that the marketing and development teams have well-analyzed reasons for making the choices they did *based on the metrics which guided them.* This study is not intended to question their decisions, but rather to take a look at how those decisions drove cost throughout the life of the processor platform. Consequently, the view of this project is from a manufacturing / order fulfillment perspective, and should not be used in any way to analyze the decision quality of HP's marketing and development groups. In this thesis, data has been disguised in order to protect the interests of Hewlett-Packard Company.

SIGNIFICANCE OF THE PROBLEM

First, it is necessary to understand the culture of Hewlett-Packard as well as the path a workstation takes through its life. Hewlett-Packard was founded as an engineering company and has found its niche by offering high quality, technically advanced products geared to meet the needs of engineers and scientists. In the 1980's, HP began to offer consumer driven products, but held on to the importance of designing superior products.

Due to the culture of HP, the voice of the customer, and satisfying the customer's latent needs is paramount in the conception and design specifications of products. Therefore, it is not surprising that most of the product constraints and performance characteristics are determined by the Marketing department. After the product performance and appearance metrics have been determined, the project is then handed off to the development stage. Development takes a number of forms in any complex product, including system development as well as component development. The definition of the components and the system is determined concurrently, but the development of the components is done individually, then brought together into a prototype product.

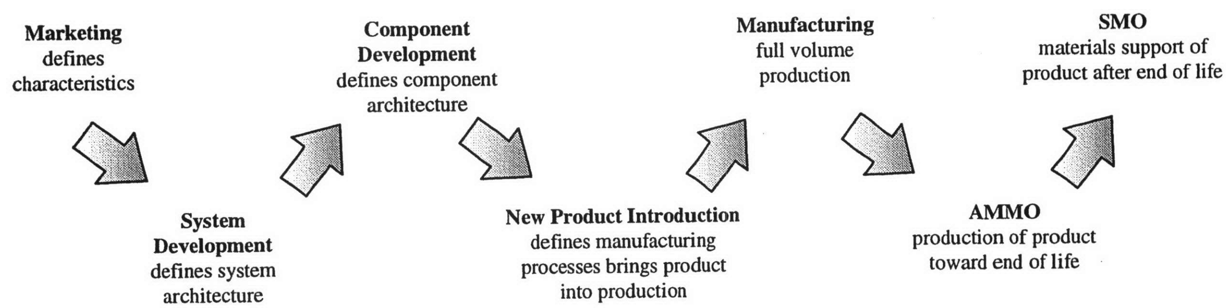

Figure 1 Stages of workstation life: conception to after end of life

Before the workstation is released for a system qualification, each of the internal components must go through electrical, mechanical, safety, or other distinct qualifications. As the system is brought together, it is handed off to the New Product Introduction (NPI) groups who work closely with development, marketing, and manufacturing to insure that everyone is satisfied with the product, i.e., that all constraints have been satisfied. The system, through the NPI team, is sent through system qualifications and brought into full production within each of the manufacturing facilities world wide. As the workstation nears end of life, and volumes decrease, production is moved into AMMO, a low-volume, job shop environment which is similar to the mainline manufacturing in process. After end of life, the Supply Materials Organization (SMO) takes responsibility of the workstation, spare parts, and servicing of its installed base for a period of five years after the last workstation is produced.

Though the marketing functions determine product performance and constraints, development determines the material cost, which currently comprises between 80% and 85% of the total costs over the life of the workstation family. There is a separate development team working to design each workstation family at HP. So, the team developing Family A may not come in close contact with the team concurrently developing Family B. This may be where a disconnect occurs with the use of platform leveraged components, as each team is designing their own unique parts to optimize performance of their particular platform. Also, each development team is measured, as a financial bottom line, on the manufacturing cost of the workstation. They are given a dollar figure, estimated as the manufacturing cost of the system, and instructed to stay below that amount. As long as they have developed a workstation with a projected material cost below this figure, they have satisfied their metric. Development teams are not focused on the costs of all systems, supply chain complexity, or the possibilities that they may have been able to develop a box which would cost half of the projected amount, if some of the constraints were relaxed. In short, the people who have the biggest hand in determining the final cost of the workstation platform over its life are not measured in any way that may push to focus on these costs or to reduce the costs. In addition to the straight material cost, there are many infrastructure costs which are driven by, and measured on, the material cost. The big hitters in infrastructure which is driven by material include Field Engineering, Supply Maintenance Organization (the after-sales support division for Hewlett-Packard), inventory holding, material engineering, and procurement.

Along with these cost impact areas, any engineering decision which does not take advantage of industry standard or platform leveraged components affects a myriad of functions throughout the life of the product. Many of these functions are listed below:

- ***Planning and Documentation:*** As the number of distinct part numbers increases, personnel necessary to support inventory management, manufacturing processes, bill of materials management, and manufacturing planning schedules increases.

- ***Procurement:*** The time necessary to manage supplier relations for a uniquely designed component is greater that that for an industry standard component. Similar to the planning function, the number of distinct part numbers forces an increase in headcount to support the purchase of the components.

- ***Test:*** Test routines must be developed for each component which is offered in the workstations. If a component is used in more than one workstation, the same test programs may be used for both systems. If, however, components in each workstation are unique, a separate testing code must be developed to support each of the unique components. In the case of the testing function, it does not matter whether the component was internally designed or purchased off-the-shelf.

- ***Tooling:*** For any new component which is designed, appropriate tooling must be developed for use by the suppliers. This additional tooling adds cost to the components, whether the cost is rolled into the component price or is charged to the workstation manufacturer separately.

- ***Qualifications:*** Material qualifications must be performed on three levels: component, interconnect, and system. If one part is leveraged between systems, the component qualifications do not need to be duplicated. If two parts are leveraged between systems, the interconnect qualifications between these two parts does not need to be duplicated. Qualifications add cost in engineer's time and the cost of the component. As parts are going through qualification, their cost could be as high as four times the cost during full-volume manufacturing.

- ***Delivery performance, Assurance of Supply, Re-work, Obsolescence Exposure, Cycle Time:*** Each time a component is added to the system, especially if it is uniquely designed, risks as to the above mentioned performance metrics increase.

- ***Inventory Levels, Risk Pooling:*** When components are used in one workstation, rather than in many workstations, inventory levels must rise in order to maintain the same desired service level to the manufacturing floor. Consequently, risk pooling which could be taken advantage of in order to further reduce inventory stock levels would not be available if components were not platform leveraged.

- ***AMMO (low volume / job shop):*** As the workstation approaches the end of its production life, it is moved to a low volume, job shop area called AMMO. In order to maintain delivery levels which will satisfy customers, components needed to produce all workstation families for the shift must be available. As the number of platform leveraged components decreases, the amount of material on the floor must increase. Along with added difficulties in the manufacturing process due to increased material, the risk of damage to the inventory increases as more is placed on the job shop floor.

- ***Failure Rates:*** Uniquely designed components will typically have higher failure rates toward the beginning of their life. As the supplier works down the learning curve and corrects the causes of the failure rates, or the designers find it necessary to re-design the component, the failure rates may equal or exceed those of industry standard components. However, if the components are not leveraged across multiple platforms, it is likely that the product's end of life will come before the failure rates are adequately reduced.

- ***Spare Parts Support and Field Support:*** All components must be held in support inventory for a number of years after production ends on the workstation. Non-leveraged components cause higher inventory and reduce opportunities for risk pooling of material.

OBJECTIVES OF THE INVESTIGATION

The basis of this research is focused on answering the following two questions:

- What volume increment is necessary to cover the cost of using unique, non-platform leveraged components in the workstation design?

- What cost reductions could HP make while maintaining the same operating profit if a larger percentage of industry standard components were used in place of unique, non-platform leveraged parts?

SCOPE AND LIMITATIONS OF THE PROJECT

This project studies the costs associated with the Apollo 260 workstation produced by Hewlett-Packard throughout the life of the workstation, including all infrastructure necessary to support the development, manufacture, and field support of the workstation and the materials necessary in constructing the workstation. Scenarios outlining the possibilities for materials choices in the workstation if either industry standard or platform leveraged components had been used and associated cost savings which could have been realized are contained herein.

This project is a post-mortem study. The changes suggested cannot be directly implemented by HP. It is the hope of the author that the lessons learned from past materials choices, and outlined in this study, will be of benefit to HP in their future workstation designs.

As this project looks at the life of one low-range workstation produced by Hewlett-Packard's Exeter, NH manufacturing division, it is in scope limited. First, the study is not intended to give an accurate description of total costs which could be saved on each workstation processor platform, but rather areas which can be significantly improved, using the cost savings for the Apollo 260 as an example of the possible scale of cost savings. Second, the project is limited in that it does not fully consider the strategic decisions and their effect in the design stages of the workstation. The majority of the limitations are listed in the following section.

ASSUMPTIONS AND DEFINITIONS

Assumptions

The major assumptions are listed below, with the balance of detailed assumptions listed in the appendix:

- The volume of workstations sold over the life of the product does not change in any scenario. This protects the outline of the project in its efforts to de-couple findings from marketing and forecasting concerns.

- The volume over the product life is assumed to be 20,000 units, which is consistent with historical and currently forecasted demand of similar level products.
- The product life of the Apollo workstation is 18 months, which is consistent with typical product life in the workstation industry at the time of this study.
- The connect rates for components as they stand at the time of this study is assumed to be the constant average over the life of the product. Since the Apollo 260 is in full production mode at this time, the connect rates currently utilized are extremely close to life averages.
- The percentage of Hewlett-Packard's world wide workstation infrastructure costs allocated to the Apollo 260 are equal to the percentage of the processor's volume as compared with HP's world wide workstation volume.
- The percentage of components used in Apollo compared to other workstations is constant over the life of the processor.

Definitions

- ***AMMO:*** Low volume and job shop assembly and test area.
- ***Box:*** Another term for one workstation.
- ***Component:*** Major sub assembly of a workstation.
- ***Connect rate:*** The average number of systems built which contain the given component. For example, for the Apollo 260 a floppy drive has a connect rate of 0.27. Thus, 27% of the Apollo 260 workstations built over a given period of time will contain a floppy drive.

- ***CSO:*** Computer Services Organization.

- ***FAST:*** Final Assembly and Test.

- ***Industry standard:*** A component is considered to be industry standard if it employs standard technology with minimal tooling, development, and cost for the supplier due to unique requirements, and requires minimal development time for the manufacturer.

- ***MRP:*** Materials Resource Planning system – an inventory, order, and manufacturing planning software.

- ***OEM:*** Original Equipment Manufacturer

- ***PCA:*** printed circuit board assembly

- ***Platform leveraged:*** A component is considered platform leveraged if exact part number is used for more than one product family, and the component is not considered to be industry standard.

- ***SMO:*** Support Materials Organization.

- ***SPaM:*** Strategic Planning and Modeling team.

- ***SWIIM:*** Strategic Worldwide Initiative Integration Management team. SWIIM performs long range planning analysis for WSY.

- ***WSY:*** Workstation Systems Division

Methods and Materials for Investigation

In order to research the components, their costs, and issues relating to whether or not they are industry standard or platform leveraged, interviews with approximately 120 HP employees including commodity buyers, strategic planners, manufacturing, quality, and planning personnel, and engineers working with new products and current products were conducted. Benchmarking and verification was determined through conversations with corporate procurement engineers. HP's scenario planning team, SWIIM, and scenario modeling team, SPaM, were utilized to help in developing models and analyzing information. Models developed by SPaM, SWIIM, and SMO were leveraged for this study and integrated into a self-designed modeling structure.

Preview of the Rest of the Report

This thesis is divided into four chapters. In the first chapter, the problem has been introduced. In the second chapter, description around the modeling techniques used are presented. In the third chapter, various scenarios are presented, explained, and analyzed. In the fourth chapter, conclusions are given, as are recommendations for further study.

Chapter Summary

As Hewlett-Packard's Workstation manufacturing division (WSY) moves into the future with its workstation manufacturing, a serious look has to be taken at the costs incurred through design of unique components. By the turn of the century, it is expected that the face of the workstation industry will change substantially, due to new entrants driven by Intel and Microsoft, and profit margins will decrease as workstations become more modular and commoditized. In order to capture the lifetime costs associated with internally developing unique components as opposed to using off-the-shelf industry standard parts or even leveraging components designed for other models within their workstation portfolio, one low-end recently released workstation was examined, the Apollo 260. It will be shown in the remainder of this thesis that approximately $27.1 million (10% of the lifetime costs for the processor platform) could have been saved by utilizing available industry standard components.

II. MODELING

What Do We Have to Work With?

The main goal of the Workstation division (WSY) at Hewlett-Packard is to increase operating profit. As the margins in the workstation industry decrease, increasing operating profit will become vital. Currently, the operating profit of WSY is similar to the profit realized by the PC division of HP, even though the gross margins in workstations is magnitudes greater than what is seen in personal computers. In order to scope the costs which cut into the operating profit, and to look for avenues to increase the profitability of WSY, two routes were examined: the cost of material for the Apollo 260 workstation, and the infrastructure necessary to support those parts. Comparisons were made with scenarios in which a larger number of parts were industry standard or platform leveraged. On the material side, the fewer components which are industry standard or leveraged, the farther out on a limb HP places itself in terms of demand variability of the components, lead time variance, part cost, risk pooling of material, forecast error, cost of quality, and transportation costs, among others. Each of these areas increases the material cost of sales and increases inventory write-offs due to obsolescence, scrap, defects, and inventory shrinkage, thus cutting into the operating profit which could be realized. Looking down the infrastructure path, non-industry standard and non-platform leveraged components increase the number of parts to be supported, the number of suppliers, and the number of processes, including part life support, necessary to maintain manufacturing continuity. Consequently, more people, and thus a larger infrastructure, is necessary to support the proliferation of parts, suppliers, and processes, also cutting into the realizable operating profit.

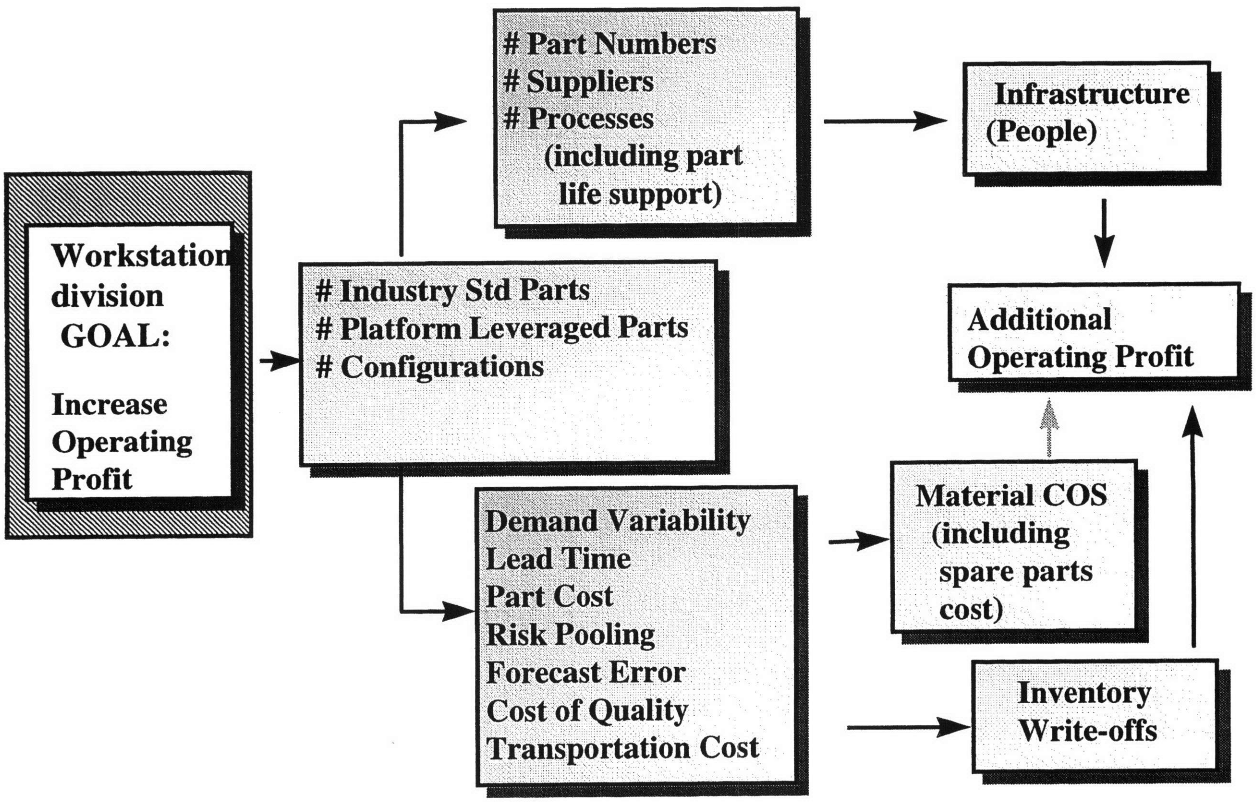

Figure 2 Modeling flow chart of cost effects

This suggests that increasing industry standard or platform leveraged parts would in turn increase operating profit. What remains is to determine how to capture and classify the effects of these component changes, and how much additional operating profit could be realized through such changes.

First, it is necessary to examine the component currently used in the Apollo 260. There are a number of components within the Apollo 260 which are not currently industry standard, but where industry standard components do exist which could be utilized by HP without decreasing their competitive advantage. Components which fall into this category include the power supply, I/O PCAs, monitors, and graphics. Likewise, there are components which are not currently leveraged across platforms which could be with future designs. Falling into this category include I/O PCAs, monitors, labels / packaging, and hardware.

Component	Change to Leveraged Across Platforms	Change to Industry Standard
Power Supply		✓
I/O PCAs	✓	✓
Monitors	✓	✓
Graphics		✓
Labels / Packaging	✓	
Hardware	✓	

Figure 3 List of components which could be changed to industry standard or leveraged across platforms

OVERVIEW OF MODEL BUILDING

In order to better capture the costs associated with using components which are not industry standard or platform leveraged, it was necessary to obtain current costs within eight basic areas, as well as how those costs would change if industry standard or platform leveraged parts had been chosen in the design of the workstation. Microsoft Excel was used for this model. The remainder of this chapter is devoted to a description of the eight areas within infrastructure, inventory holding, and material costs, development of the model used to evaluate total cost over the life of the processor, and scenarios considered to determine the impact on cost had alternate material choices been made.

Major elements

Eight major elements of cost exist within the development of the model used: Infrastructure, Inventory, After Production Support, Material, Transportation, Supplier, Quality, and Manufacturing. While detailed cost categories exist within most of these larger categories, the extent to which each effects the total cost of the system varies greatly. The following section describes in detail the composition of cost drivers, as well as specific modeling used within each of the elements. The chart below defines the hierarchy of cost categories which are explained throughout the remainder of the chapter. Many of the lowest level cost categories were omitted from this chart for clarity, though all cost categories considered are listed in the Appendix.

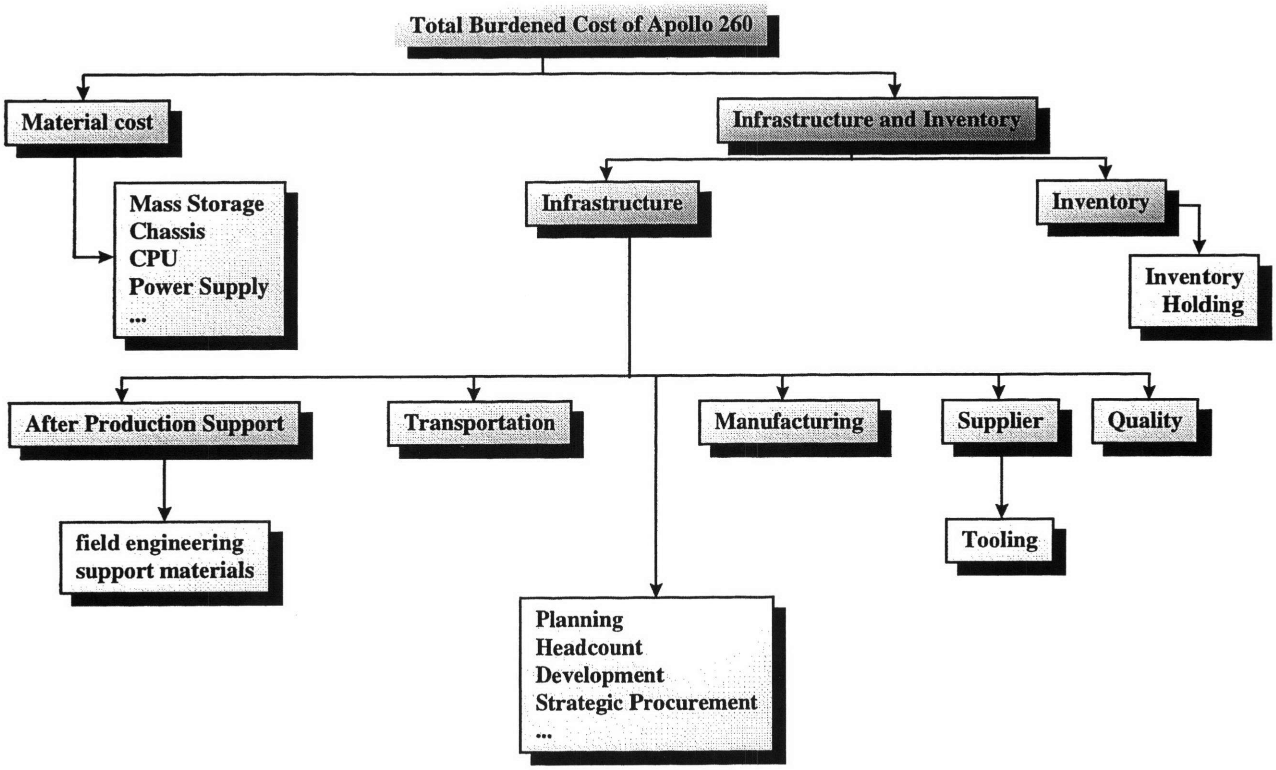

Figure 4 Hierarchy of cost categories

The highest level is to consider the total, burdened cost of the workstation throughout the product's life. Digging down one level, we can divide the burdened cost into two categories: (1) materials cost, which is comprised of the bill of materials cost for producing the workstation in full-production mode, and (2) infrastructure and inventory costs, which capture the indirect costs associated with the workstation over the processor's life as it is supported by HP. Infrastructure costs can be broken down into strict infrastructure costs, such as development and production costs, as well as transportation costs, cost of quality, and after production support costs. Within each of these areas further detail can be defined.

Resolving Leveraged Components

For accurate modeling of the components and processes which affect the cost of the workstation, it was necessary to detach the costs associated with the Apollo 260 from the total cost of given functions and component procurement without altering dynamics of the system. For example, if we were to determine the costs associated with developing a new power supply and attributed the total development cost to the Apollo 260, even though the power supply is leveraged across other platforms within WSY, the total cost of developing the Apollo 260 would be overstated. Similarly, accounting the inventory holding cost of the power supply to Apollo 260 would also overstate the cost. Conversely, if the inventory holding calculations were based on demand and standard deviation of demand for the Apollo 260 exclusively, the amounts which would be charged to the workstation could be either overstated or understated due to the nature of the standard deviation. Therefore, the total demand for each component is used in calculating all cost elements, with the percentage of the demand used in Apollo 260 of the total demand for the component being the actual cost allocated to the workstation's total burdened cost, i.e.,

Cost of component attributed to Apollo 260 = (total cost of component) / (percentage of total demand for component which is attributable to the Apollo 260)

$$\text{Cost of component attributed to Apollo 260} = \frac{\text{total cost of component}}{\text{\% of total demand attributable to Apollo 260}}$$

The demand which is directly attributable to the Apollo 260 is determined by the demand of the Apollo 260 CPU (central processing unit), the only element in the workstation which has a 100% connect rate, i.e., there is a one to one demand relationship between Apollo 260 workstations and Apollo 260 CPUs. It should be noted that many of the components used in manufacturing an Apollo 260 workstation are optional components. Thus the connect rate shown is less than 100%, yet the component is not considered to be platform leveraged.

DESCRIPTION OF ELEMENTS

The methods for determining the cost in each of the major categories is listed below. Actual data compiled is shown in the Appendix.

Infrastructure Costs

Infrastructure costs represented include costs to Hewlett-Packard which are attributable to the development and support of the Apollo 260 workstation. In order to capture these costs, it was necessary to collect information, estimated in some cases, regarding the personnel time and resources expended during the processor's development. Many of the component costs were available as a portion of the total development cost, rather than as individual contributors to the total cost of the workstation. It was necessary, therefore, to determine the total cost and reconcile to component cost in a later step. The reconciliation process is described later in this chapter. Areas of cost which fall into this category include:

- ***Headcount:*** Calculated by summing the worldwide headcount costs for workstations over a 1.5 year period, multiplying by the percentage of worldwide workstation revenue volume over a 1.5 year period which is attributable to the Apollo 260 workstation. The Current Product Engineering, Test Development and Implementation, Incoming Material Test, and Strategic Procurement headcount figures were eliminated from the above summation in an effort to more accurately capture these costs, as they are all functions which have potential for significant improvement under various materials choice scenarios.

- ***Current Product Engineering:*** Calculated as the cost of engineering time for full project - based on 0.7 engineer/month over the life of 8 months. It is estimated that for 2 distinct projects, it would take 16 months of manpower, where if the second project were leveraged off of the first, the second project would take only 2 additional months, as opposed to a full 8 additional months, with the first project taking the full 8 months in either case.

- ***Information / Documentation:*** The development cost of new process diagrams for technical reference manuals, assembly line process packages, and user documentation.

- ***Development:*** The cost of development per component is calculated to be the development cost of the component multiplied by the percentage of total demand which is attributable to the Apollo 260. The sum of costs for all components in the workstation produce the development cost of the workstation.

- ***Strategic Procurement:*** Calculated as the sum of all cost included in procurement personnel time and associated costs in qualifying vendors, materials, and negotiating price.

The following areas / functions were considered in the cost analysis for HP Infrastructure costs, but it was determined that the cost attributed to the function was completely captured by the

Headcount costs, or that the amount not captured through Headcount costs were insignificant and could be disregarded:

- ***Design for Assembly/Manufacturability***
- ***Planning***
- ***Operator Training (Assembly and Test)***

Inventory Holding Cost

Inventory levels at Hewlett-Packard are determined through use of the base stock, or economic order quantity, method common in inventory holding literature (Jordan, et. al., 1995). The basic premise behind this method is to determine a reorder quantity, R, such that the inventory held protects for average demand during replenishment lead time plus safety stock for above-average demand. When the inventory level falls to R, a specified order amount is placed. Theoretically, this will allow the manufacturer to have raw materials inventory on hand when needed based on a given service level desired and demand variability, but will not require the manufacturer to carry excess inventory. By reducing the amount of raw materials inventory carried by the OEM, the cost of carrying the inventory is reduced and the service level to the customer is increased. The inventory holding cost is defined to be the cost of carrying the inventory between the time it arrives in the factory's warehouse to the time it is used in production. Costs can come from inventory shrinkage, obsolescence, damage, and the cost of physical space required to hold the excess inventory. This inventory holding cost is determined at HP historically as a percentage of average inventory cost incurred due to the above factors of the total inventory used over one year.

The inventory holding cost is calculated for each component individually. The total demand for the component was used to calculate this value, not simply the portion of the demand attributable to the Apollo 260 processor. Inventory Holding cost modeling assistance was provided by HP's Strategic Planning and Modeling (SPaM) team, and is a version of their single node model for inventory holding calculations. The major components used to calculate inventory holding include

- ***fill:*** the desired service level for the Exeter facility, defined to be the percentage of time an order comes in and the part is needed for the order and the part is available in inventory. The fill rate target for WSY is 98.5%.
- ***rev:*** review period of the component. Materials buyers reviewed all components using HP's MRP inventory management system weekly.
- ***freq:*** frequency of shipment receipts, expressed in weeks between receipts. Calculated as the mean time between shipment receipts over a period of six months.
- ***dem:*** mean weekly demand. Calculated as the mean total monthly demand for the component over a period of six months, divided by 4.3 to obtain weekly demand.
- ***sd:*** weekly standard deviation of demand. Calculated as the standard deviation of total monthly demand for the component over a period of six months, divided by 4.3 to obtain weekly demand.
- ***lt:*** mean supplier lead time in weeks. Calculated as

$$lt = (\text{average quoted lead time per month})$$

+ (average difference in actual lead time from quoted lead time per month)

+ (average in-transit lead time)

for a period of twelve months

- ***ltsd:*** standard deviation of supplier lead time in weeks. Calculated (Hogg, et. al., p.91) as

$$ltsd = \sqrt{Avg(actual\ lead\ time - quoted\ lead\ time)^2 - (Avg(actual\ lead\ time - quoted\ lead\ time))^2}$$

where the arguments are averaged per month over a period of twelve months. Since the standard deviation of in-transit lead time over a period of twelve months was significantly small, less than 1 day, it has been disregarded for these calculations.

In order to approximate a normal distribution for service levels greater than 81% using Microsoft Excel without creating a lookup table, is was necessary to include a number of intermediate calculations which approximate the normal distribution using the solution to the quadratic formula,

quad_a = 0.37

quad_b = 1.19

$$\text{quad\_c} = 0.92 + \text{Log}\left(\frac{\text{Q} \times (1 - \text{fill})}{\text{sdEXPdem}}\right)$$

where

$$\text{Q} = \text{dem} \times \text{freq}$$

$$\text{sdEXPdem} = \sqrt{\left(\text{sd}^2 \times (\text{lt} + \text{rev})\right) + \left(\text{dem}^2 + \text{ltsd}^2\right)}$$

The equation sdEXPdem calculates the standard deviation of the pipeline demand. The pipeline consists of the supplier lead time plus the review period.

Additional intermediate calculations to approximate the normal distribution include

$$\text{temp\_y} = \max\left(0, \left(\text{quad\_b}^2 - 4 \times \text{quad\_a} \times \text{quad\_c}\right)\right)$$

$$\text{temp\_x} = \frac{-\text{quad\_b} + \sqrt{\text{temp\_y}}}{2 \times \text{temp\_a}}$$

The maximum function is added into temp_y to insure that the positive root of the quadratic equation is used to accurately represent the desired service level, demand, lead time, and standard deviations of demand and lead time provided. Any negative root of the quadratic equation would not only represent an incorrect approximation, it would be technically unfeasible since it is impossible to have negative values for any of the input variables.

The final calculations in determining the inventory is

Safety Stock Inventory = temp_x × sdEXPdem

Cycle Stock Inventory = freq/2 × dem

Average Inventory = Safety Stock + Cycle Stock

In-Transit Inventory = Mean Demand × In-transit time

Total Inventory = Average Inventory + In-Transit Inventory

Multiplying the total inventory by the cost of the component, the value of inventory can be determined. From this, the inventory holding cost, defined as the cost of inventory damage, obsolescence, shrinkage, and physical holding, is determined as

Inventory Holding = Value of Inventory × (25% + 7% cost of capital)

After Production Support Costs

Two main areas comprise after production support costs: (1) field material usage, and (2) the supply materials organization. Each of these organizations support material after production ends for products coming from all divisions of HP, not just the workstation and server divisions. Field material usage refers to the material and carrying costs associated with engineering service and repair in the field. This will include machine set-ups and replacement of incorrect or damaged components. The support materials organization (SMO) is responsible for supporting components for a period of five years after the end of production. Components which can be refurbished or repaired after production ends instead of scrapped are brought into SMO. Similarly, SMO is responsible for supporting material for all HP equipment for an extended period of time and is responsible for the material and carrying costs. Information and modeling assistance for the after production support section of the model was provided by SMO. The total demand for the component was used to calculate these values, not simply the portion of the demand attributable to the Apollo 260 processor.

Field Material Usage: The field material usage is defined to be the amount of material that will be necessary to service an installed base of machines for twelve years after the end of production. The total demand for field material over the twelve year period is calculated as demand = installed base × AFR

where AFR is the annual failure rate of the component. The majority of the forecasted material needed is expected to be used within the first half of the support life, as shown by the figure below.

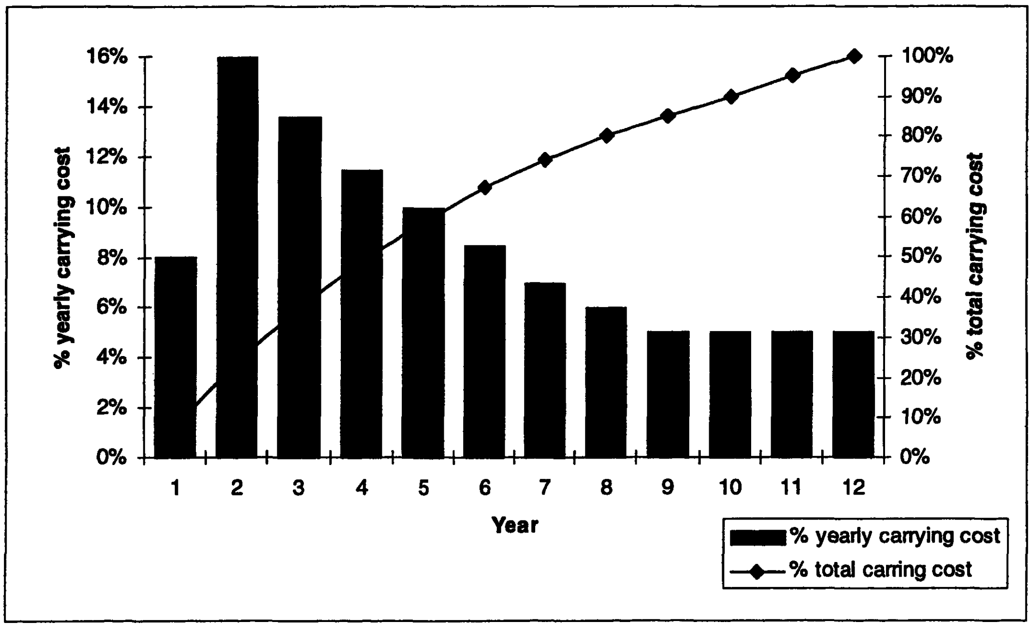

Figure 5 Material demand for Field Material Usage

The support cost for a component after production is then calculated to be

$$\sum\left(\tfrac{1}{2}\times(\text{current material cost})\times(\text{demand per year})\right)$$

summed over the 12 years of product support.

Supply Materials Organization: Unlike field material usage, supply materials organization works under the assumption that no more than 100 units of inventory for any given item are expected to be in stock at any one time, regardless of the installed base for the component. The total costs for any component supported by SMO is calculated to be the

$$\sum(\text{carrying cost} + \text{lost opportunity cost}) + \text{field scrap cost}$$

summed over the seven years (1.5 years of production, 5 years of support) the component is supported.

The carrying cost per year is calculated as

$$\text{Carrying cost per year} = 15\% \times (\text{material cost})$$

with a 15% decline rate per year beginning in the third year. Thus the inventory holding calculations for any component supported by SMO has the following characteristics:

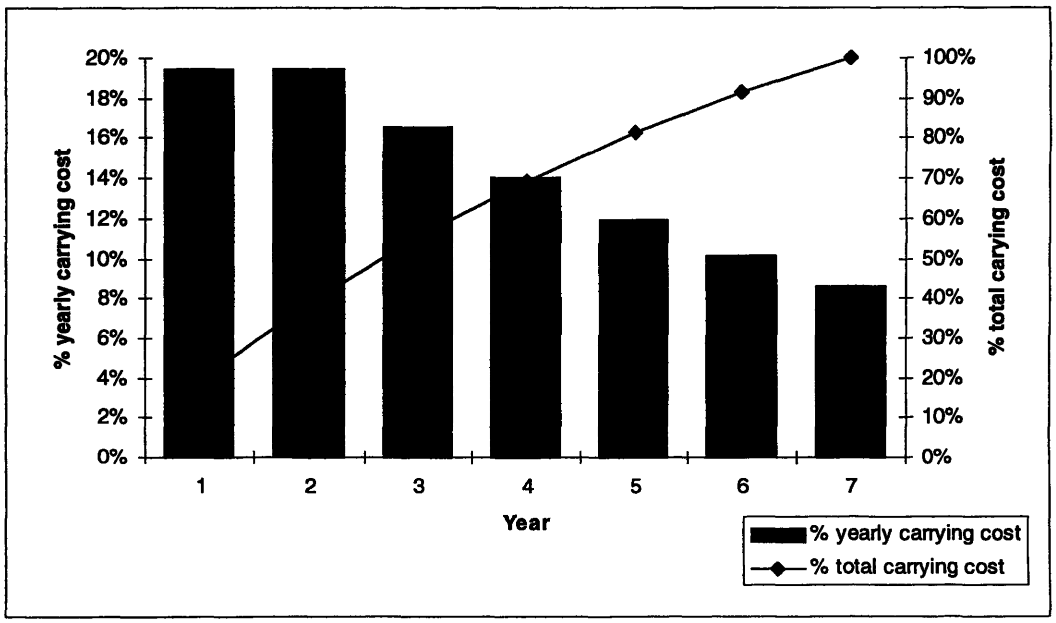

Figure 6 Carrying cost for Supply Materials Organization

Lost opportunity cost is calculated to be 15% of the cost of the component multiplied by the amount of inventory forecasted to be held. In the third year, the calculated opportunity cost is decreased by 15% per year for the remaining years.

Field scrap is calculated to be 75% the cost of the component multiplied by the average amount of inventory per year forecasted for the seven years of support.

Material Cost

The current material cost as of April 1, 1996 for each component was obtained. Cost of industry standard or platform leveraged materials which were comparable in performance but not used in the Apollo 260 were also obtained.

Transportation Cost

Air, ocean, and land transport costs were obtained per commodity. Using data over a six month period, the average percentage of components shipped through each channel was calculated. The transportation cost per component is calculated to be:

$$
\begin{aligned}
\text{transportation cost} = {} & (\$\text{ air x-port}) \times (\%\text{ air x-port}) \\
& + (\$\text{ ocean x-port}) \times (\%\text{ ocean x-port}) \\
& + (\$\text{ land x-port}) \times (\%\text{ land x-port}) \\
& + (\text{duty cost (if sourced off-shore)})
\end{aligned}
$$

Supplier Costs

- ***Supplier Tooling:*** The cost required to manufacture and assemble unique tooling for the supplier which is required in order to produce components which are required by HP only. In all components for the Apollo 260, it is not expected that tooling will need to be replaced.
- ***PCA Setup:*** Calculated as the overhead incurred per year from board changes within HP's PCA manufacturing division, allocated to each board they produce based on the volume of

the board. This number is multiplied by 1.5, to cover the production life of the processor, and the number of boards included in the Apollo 260.

- ***Assurance of Supply and Delivery Performance:*** Though these costs for all components were included in the Strategic Procurement cost, the items are mentioned here for completeness.

- ***Risk to Hewlett-Packard:*** Defined as the cost of inventory (in any stage) which the supplier charges to HP for material which can be sold only to HP and must be scrapped or retrofitted for another OEM, multiplied by the percentage risk that demand will fluctuate outside of the range acceptable for the supplier as negotiated in their contract.

Cost of Quality

- ***Initial Qualification:*** Cost per system is calculated as

Initial qualification = 4 × (material cost of system) × (number of qualified systems).

Usually 48 units go through qualification. If the product is platform leveraged, only 54 systems total (as opposed to 96) would need to be qualified. For this calculation, it is assumed that the systems may be sold, thus the unrecoverable cost is

3 × (material cost) × (number of qualified systems).

There is a risk, however of the systems failing qualification and being scrapped. It should be noted that neither the risk nor the additional cost has been modeled here.

- ***Material Qualification:*** Material qualification costs were often included in contracts between HP and the supplier. For internal suppliers, it is assumed that even though the WSY division is not saddled with the cost of material qualification, it is still a cost to the company, thus it is included in this study. Items such as power supplies or PCA boards must pass additional safety qualifications. The Material Qualification costs is a summation of all such costs.

- ***Incoming Material Test:*** Calculated as

Incoming Material Test = Average number of parts per hour which can be inspected

× lot batch inspection size

× labor rate

The variability for this function is significantly low, thus for the purposes of this model it has been omitted.

- ***Test Development / Implementation:*** Calculated as the estimated work hours (weeks) of time required to develop and implement test procedures on a new component, multiplied by the cost of a fully burdened engineer.

Manufacturing Costs

All significant manufacturing costs are captured in (1) Headcount costs for the personnel, (2) Inventory Holding, which accounts for the cost of capital, and (3) Cost of Quality, in the areas of incoming material test, and test development and implementation. Although there are no additional costs attributed to the model directly through the manufacturing function, the element of possible cost is noted for completeness.

COMPILATION OF THE MODEL

From this point on, the model consists mostly of simple arithmetic. First, three major categories of cost had been determined: Infrastructure, Material (or Component), and Inventory. All of the Infrastructure costs captured were previously scaled to a direct one to one relationship with the Apollo 260 workstation. However, Component and Inventory costs have not yet taken into account the differences in demand between total component demand and the percentage of that demand which is directly attributable to the Apollo 260. Therefore, to calculate the total component cost for the workstation, the total cost for each component is multiplied by the percentage of demand which is directly attributable to Apollo 260. The sum of such adjusted component costs, multiplied by the forecasted 20,000 unit volume and the component connect rate, makes up the given Component cost category. Likewise, the total inventory holding cost is calculated in a similar fashion.

By simply adding the Infrastructure, Component, and Inventory costs, it is possible to get the burdened cost of the workstation. The average burdened cost per workstation sold is equal to the burdened cost of the workstation divided by the 20,000 unit volume.

Platform Leveraged and Industry Standard Calculations

The above calculations to determine the current cost for the workstation was repeated in determining projected costs of the Apollo 260 workstation had platform leveraged or industry standard components been used. Some of the information used for the projected costs was not available, thus approximations and assumptions were necessary. A list of the detailed assumptions are found in the Appendix.

SCENARIO BUILDING

Up to now, the total current cost of the Apollo 260 workstation has been determined, and the projected costs for a workstation using additional platform leveraged components (I/O PCAs, monitors, labels / packaging, and hardware) or additional industry standard components (power supply, I/O PCAs, monitors, graphics). Necessity called for determination of the relative importance of changing each component, i.e., scenario analysis, and sensitivity analysis surrounding key components. Extensive sensitivity analysis was conducted surrounding cost estimates in either industry standard or platform leveraged scenarios, to gain an understanding of the importance of accuracy in those cost categories.

Scenarios

Forty five scenarios were considered to determine the relative importance of changing individual or multiple components from either industry standard to platform leveraged components. No scenarios included both industry standard and platform leveraged changes due to the complexity of assumptions which would have to be made in this case. It was the expectation that the results of such an analysis would produce a "garbage in, garbage out" effect due to a large number of unknowns.

For each scenario, some but not all of the components were changed, as were the associated data categories. In order to accomplish this, an Excel spreadsheet was developed which would gather Material cost and Inventory cost information from one of three categories: "HP current costs", "Platform Leveraged costs" or "Industry standard costs."

When some, but not all components were changed, it was necessary to alter the Infrastructure costs, based on a weighted average between the scenario the component was moving from to the scenario the component was moving toward. If there were not many component changes, it was reasonable to assume that the infrastructure costs would not be greatly affected, since the majority of infrastructure costs are internal to HP in the forms of headcount and related functions. In practice, it is not feasible to remove a fraction of a person, which would occur in the model if minor process changes were made that did not have a significant effect on the internal infrastructure. Thus, a minimum of 50% of the total possible component changes had to have been made for the scenario to alter the infrastructure category.

Letting the possible change in infrastructure cost be given as the difference between the current infrastructure cost and the industry standard or platform leveraged infrastructure cost, the calculation for determining changes in are as follows:

% of possible components changed	% of possible change in infrastructure cost
50%	20%
75%	50%
100%	100%

Figure 7 Scenario reconciliation of infrastructure cost changes

CHAPTER SUMMARY

To capture the costs which could be saved through use of industry standard components or platform leveraged components, costs relating to a component throughout the processor life were captured. The industry standard components which were examined include: power supply, I/O PCAs, monitors, and graphics. The platform leverageable components which were examined include: I/O PCAs, monitors, labels, packaging, and hardware. Cost categories which were examined include: infrastructure, inventory, after production support, material, transportation, supplier, quality, and manufacturing. Using a Microsoft Excel spreadsheet model, costs attributed to each of these categories for each component were captured. In order to equitably attribute the cost of a component which is used in additional workstations other than the Apollo 260, the total costs attributed to the component was multiplied by the percentage of the part used for Apollo 260 workstation manufacture. Additionally, components which were considered both platform leveraged and industry standard were classified as "industry standard" in order to simplify modeling processes. In order to determine components adding the highest cost to the system, or those which would give the biggest cost savings, forty five scenarios were examined. Sensitivity analysis was performed on each of the scenarios to ensure cost savings were within a range to produce accurate results.

III. THE RESULTS

EXAMPLE OF COSTS FOR I/O PCA CHOICES

Taking as an example of the costs that accumulate through the life of the workstation, on the Apollo 260, a decision was made to use non-industry standard I/O PCAs, even though industry standard components which could match the technical specifications exist. The limiting factor which drove the decision to use internally designed components was the size and packaging of the I/O PCAs which were available through standard suppliers at the time of development. The material cost, which determines the largest portion of cost within the workstation, is 35% higher ($150 compared to $97) for the chosen component over comparable performance I/O available. When the difference in cost, $53, is multiplied by the projected volume for workstations of 20,000 units of the 18 months of the processors life, an additional $1.06 million is added to the total cost of the platform. While this is the largest area where savings could be realized with the I/O, the decision creates a domino effect, driving costs throughout the supply chain. The areas most significantly impacted by this decision are listed below.

- ***Strategic procurement:*** The cost of strategic procurement, $5,000, while not a large amount in itself is significant in that the function could be virtually removed if industry standard components were used. The effort involved in acquiring and maintaining suppliers which can handle the uniquely designed component at relatively low volumes while maintaining high levels of quality and on-time delivery is far higher than if industry standard components were used. Another point to note is it is usually necessary to single source unique components while multiple sources are typically available for industry standard components. This increases the level of dependence of HP on a specific supplier, thus the effort to make sure that supplier is living up to the standards HP has set is also increased.

- ***Initial qualification:*** The initial qualification function involves verification of the system performance and reliability. This cost could be reduced by 27% by utilizing industry standard components, from $34,000 to $25,000. The principle costs in qualification are in engineering time and risk of material scrap. When a uniquely designed part is produced for qualifications, the cost of the part is typically four times that of the production volume cost. If the system passes all qualifications, it can be sold, though the extra material cost is not recovered. If the system fails any qualification, it must be scrapped and set back to development. Taking into account the difference in probability of industry standard components passing qualification and uniquely designed components passing qualification, notable savings could be realized in this area.

- ***Test development and implementation:*** For each new component, new programs need to be written and implemented in order to adequately test the functionality of the element, at a cost of $20,000. If the component was industry standard, the process for testing functionality would already be determined, thus the effort required to produce test routines would be minimal – virtually zero.

- ***Inventory holding:*** Since inventory holding is directly tied to the cost of the component, the savings seen in inventory holding costs would mirror savings seen in material cost. Other factors, such as shrinkage and obsolescence would also reduce the inventory holding exposure by 83%, from $74,000 to $12,000 with the use of industry standard parts.

- ***After sales support:*** As with inventory holding costs, after sales support costs are directly linked to the materials cost of the component, since the measure of cost for after sales support includes the cost of holding components for field service for a period of five years after production on the specific processor ends. When taking into account the likelihood of failure of the component over said five year period, a change to industry standard components would reflect a 41% savings in after sales support costs, reducing the amount from $137,000 to $81,000.

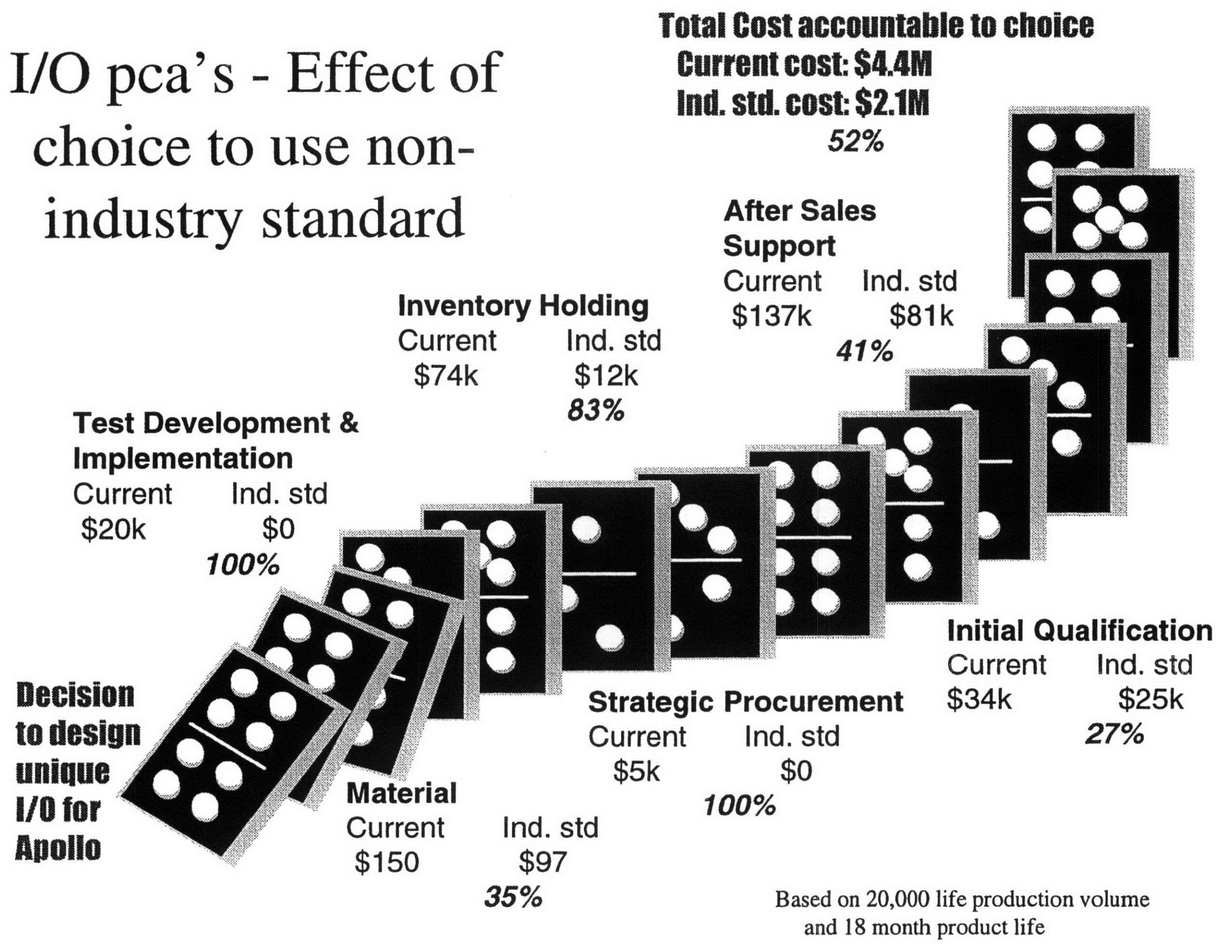

Figure 8 Cost effect of decision to uniquely design I/O PCAs for Apollo workstation

By adding all cost savings through a change to industry standard I/O, approximately 52% -- $4.3 million – of the cost associated with this one component could have been avoided.

MATERIAL COST FOR CURRENT, INDUSTRY STANDARD AND PLATFORM LEVERAGED

As shown in the example of I/O PCAs, the material cost is the hardest hitting area. When looking at other key components, such as the power supply, monitor, and graphics, it is clear that significant dollars can be saved by moving the components from unique for one box either to industry standard or platform leveraged. The associated component costs, with the percentage of cost from what is currently being sourced, is shown in the table below.

Component	Current material cost	Material cost if leveraged across platforms	Material cost if industry standard
Power Supply	$1445	$1105 (96%)	$1068 (93%)
I/O PCAs	$150	$135 (90%)	$97 (65%)
Monitor	$1512	$1436 (95%)	$1436 (95%)
Graphics	$2208	$2208 (100%)	$1877 (85%)

Figure 9 Potential material cost savings per component

The figure below represents the current component cost classifications for sub-assemblies in the Apollo 260 workstation.

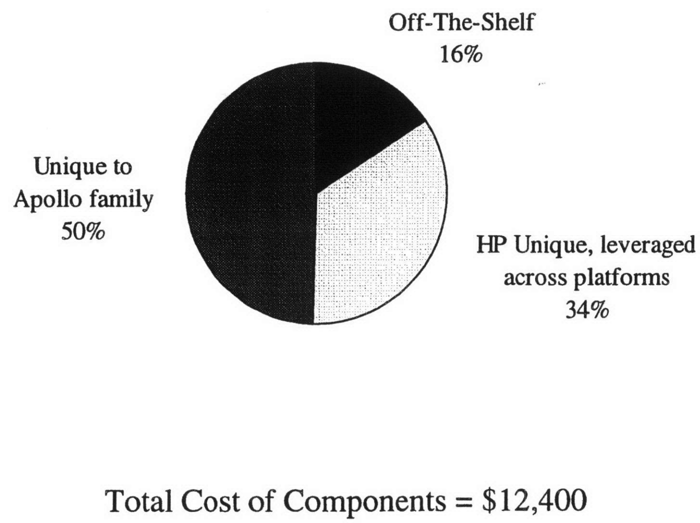

Figure 10 Current component cost categories

For the case involving a move to industry standard components, not only is the percentage of unique components decreased by 18%, but the total material cost is decreased by 8%. The figure below shows how the cost structure for the Apollo 260 would have been classified had these alternate component decisions been made.

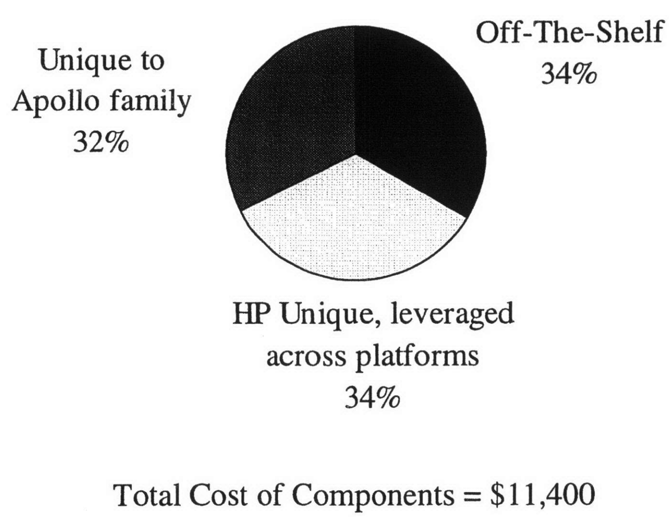

Figure 11 Proposed component cost categories

SIGNIFICANT INFRASTRUCTURE COSTS

Though the material cost is the heavy hitter in component cost, there is significant savings potential available through the infrastructure channel. As components are either leveraged across platforms or changed to industry standard, the amount of infrastructure necessary to support those components decreases. The largest in the infrastructure savings come in the areas of Development and Headcount. This should not seem surprising, as development costs would be expected to decrease if uniquely designed components would not need to be designed. With a change to either industry standard components or to platform leveraged components, the development costs are projected to decrease by 17%, dropping the total cost associated with that processor platform from $18 million to $15 million. Headcount costs would be expected to decrease 5% ($0.1 million) if industry standard components were used and 43% ($0.9 million) if previously designed components were used, allowing for platform leverage. The reason there is such an advantage in headcount to using platform leveraged parts, is that the number of processes would decrease due to the fact that there would be fewer components to support which would require fewer people. This is not necessarily true when looking at industry standard components, which would not in itself decrease the number of distinct part numbers to support. Needless to say, it is assumed that if a component is *both* industry standard and leveraged across platforms the savings would be even greater, although that scenario was not examined due to complexity of the data.

SIGNIFICANT SCENARIOS

What has been shown up to this point is the maximum cost savings which could be potentially realized by making the switch to industry standard or leveraged components. In practice, it may not be comfortable or feasible to change all components initially, so a look at the cost differences of changing some but not all of the components was conducted. Below is a chart of the seven biggest impact areas, with the percentage of total cost savings listed on the bottom line. In this chart, the first five scenarios depict changes to industry standard components. The final two scenarios show the largest cost savings for platform leveraged components. The reason platform leveraged scenarios show a significantly lower savings than the industry standard scenarios is driven by the material cost. Basically, if parts are platform leveraged, the material cost would not change significantly – it may drop slightly due to higher volumes – so the majority of the total cost (80-85%) of the system remains unchanged.

Scenarios	1	2	3	4	5	6	7
Power Supply	✓	✓		✓	✓		
I/O PCAs	✓			✓		✗	✗
Monitor	✓	✓	✓		✓	✗	✗
Graphics	✓	✓	✓	✓			
Labels / Packaging						✗	
Hardware						✗	
% Savings	***10.0%***	***9.7%***	***9.6%***	***8.8%***	***8.7%***	***4.2%***	***3.6%***

✓ = industry standard

✗ = leveraged across platforms

Figure 12 Scenario cost savings

The scenarios shown above reflect not only the material cost of the workstation, but also the infrastructure necessary to support the material. By combining the information already outlined on the material cost of components, as well as the infrastructure costs such as headcount and development, it is possible to determine the component cost per box (based on a 20,000 unit life volume), the infrastructure cost per box (based on 20,000 unit life volume), and thus the burdened cost per box (the sum of component and infrastructure costs). The burdened cost per box could drop by approximately 4% by changing to platform leveraged components and by approximately 10% by changing to industry standard components, as shown below.

	Current cost	**Leveraged cost**	**Industry Standard cost**
Infrastructure cost per box	$1.8k	$1.6k	$1.5k
Component cost per box	$12.4k	$12.1k	$11.4k
Burdened cost per box	$14.6k	$14.1k	$13.2k
% savings in infrastructure cost		12%	17%
% savings in material cost		3%	8%
% savings in total cost		4%	10%
$$$ savings in total cost (savings per box multiplied by 20,000 unit volume)		**$10.5 million**	**$27.1 million**

Figure 13 Total potential savings over the life of the product

Unfortunately, this 4% or 10% does not translate directly to the bottom line operating profit for WSY, but it can greatly effect the financial measures and possible success of the company in three main ways: comparable gross margin dollars for lower volume production, higher operating profit per box for lower volume production, and comparable operating profit for less revenue per box.

The chart below shows the relationships between revenue, gross margin, operating profit and volumes when comparing the current costs to those obtained through a changed to industry standard component use. By varying one of the parameters, such as Cost of Sales, the corresponding volume, gross margin, or operating profit measures can be evaluated.

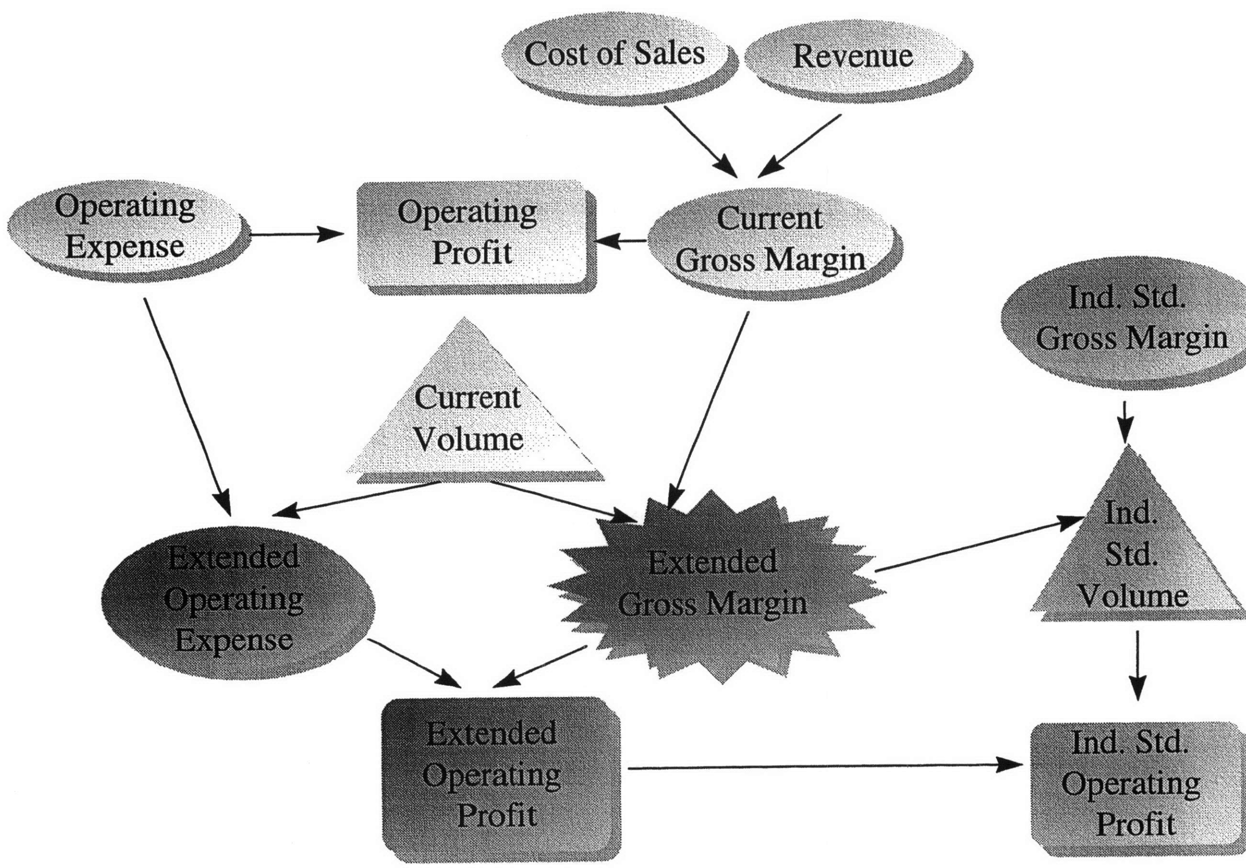

Figure 14 Method for determining the magnitude of savings seen by the company

Additional operating profit or gross margin gains are explained below.

♦ ***Comparable gross margin dollars for lower life volume production:*** It is possible to obtain the same gross margin with a 17% lower projected volume if industry standard components are used.

	Industry Standard: based on 20,000 units			Industry Standard: number of units to be determined	
	per unit	EXT ($K)		per unit	EXT ($K)
Rev	$23,626	$472,512		$23,626	$392,499
COS	$17,018	$340,360		$15,671	$260,347
GM	$6,608	$132,152		$7,955	$132,152
OP EXP	$5,922	$118,444		$7,129	$118,444
OP PFT	$685	$13,708		$825	$13,708
How many fewer units for equal GM:			17%		
Number of units required			16.6		

Figure 15 Volume difference for industry standard with constant gross margin

By switching to industry standard components, the same gross margin can theoretically be obtained at 83% of the current volume. If this were to be realized, the operating profit for the remaining 17% of forecasted volume would be icing on the cake – it would be extra profit that WSY could not feasibly obtain under their current structure. Likewise, a movement to platform leveraged components would yield the same gross margin with a 9% lower volume.

♦ ***Higher operating profit per box:*** Similarly, we can take the view of how the decreased cost of sales will effect operating profit if industry standard components were utilized. As shown by the figure above, the reduction of 17% in unit volume will still allow for an equivalent extended operation profit.

♦ ***Comparable operating profit with less revenue per box:*** Finally, it is possible to obtain the same operating profit per box with a reduction in revenue obtained from sales of the workstations. This becomes critical as the competition between the workstation manufacturers increases, and lower per box costs to the customers can give significant competitive advantage.

	Industry Standard: based on 20,000 units			Industry Standard: number of units to be determined	
	per unit	EXT ($K)		per unit	EXT ($K)
Rev	$23,626	$472,512		$21,830	$436,601
COS	$17,018	$340,360		$15,671	$313,420
GM	$6,608	$132,152		$6,159	$123,181
OP EXP	$5,922	$118,444		$5,473	$109,456
OP PFT	$685	$13,708		$686	$13,725
Reduction in Revenue for same GM:			8%		

Figure 16 Revenue difference for industry standard with constant gross margin

RISK POOLING ADVANTAGES

As a byproduct of HP's drive toward manufacturing optimization, the majority of direct labor time previously required to assemble a workstation was removed. In order to accomplish this, many of the sub-assemblies for the workstations were combined at the supplier's site, then shipped to Exeter. While this decreased the assembly time, it magnified the amount of inventory required to support the facility. An example is seen in a selected disk drive, Drive A. Drive A is used in both Workstation X and Workstation Y, but the brackets used to mount the disk drive are different in each machine. In the push to reduce labor, the assembly of the brackets onto the drives is now performed by the supplier, so the goal of easier assembly is accomplished within HP. The trade-off being made is in the cost of the material and the amount of material which must be carried in order to guard against stock-out. Instead of stocking one high-cost item Drive A, and two low-cost items, the brackets for Workstation X and Workstation Y, it is now necessary to stock two high-cost items, Drive A customized for Workstation X and Drive A customized for Workstation Y.

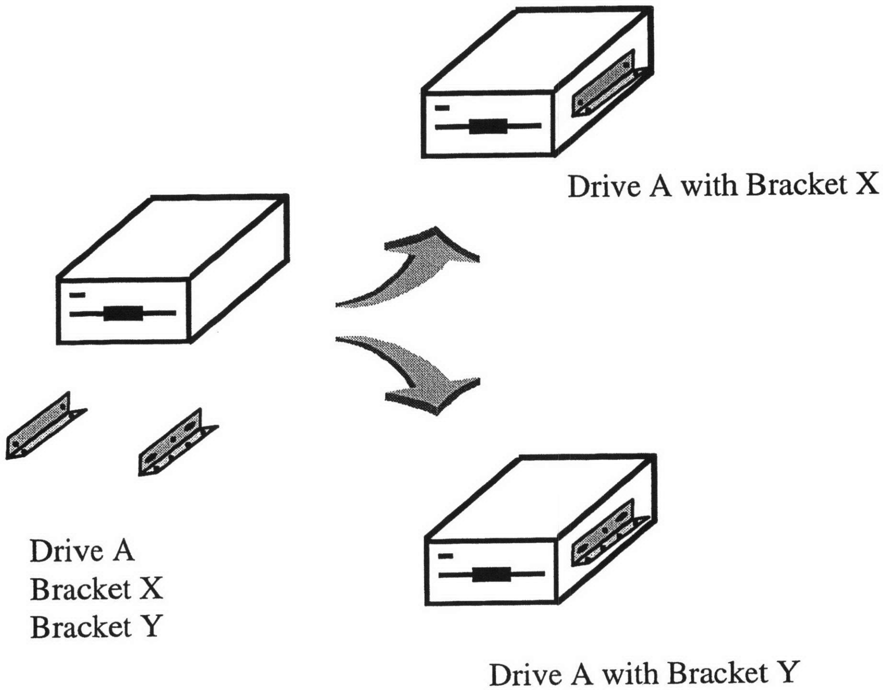

Figure 17 Combined components

There are two warning signals which can been shown in this example. First, the brackets added to the disk drive do not add any value to the performance of the workstation. Second, the high cost item is being duplicated so that risk pooling of the inventory cannot be enjoyed. A simple first question may be "why weren't the brackets designed to fit both Workstation X and Workstation Y?" One reason is each workstation was designed by a separate development group, and each group did not have constant communication with each other. Other reasons include the geometric space each drive was placed into or time differences between the development of the two machines. The main point, though, is that they were designed differently, and the cost of the drive as well as the inventory holding amount both needed to increase due to this decision. While this is a seemingly small example, it provides illustration as to the problem which was found within HP's workstation manufacturing.

By taking a look at the effect of forecasting accuracy and its effect on inventory management, this point becomes clear. The three graphs below represent the forecasted demand for three separate components over a period of 12 months. The standard deviation of demand is also shown.

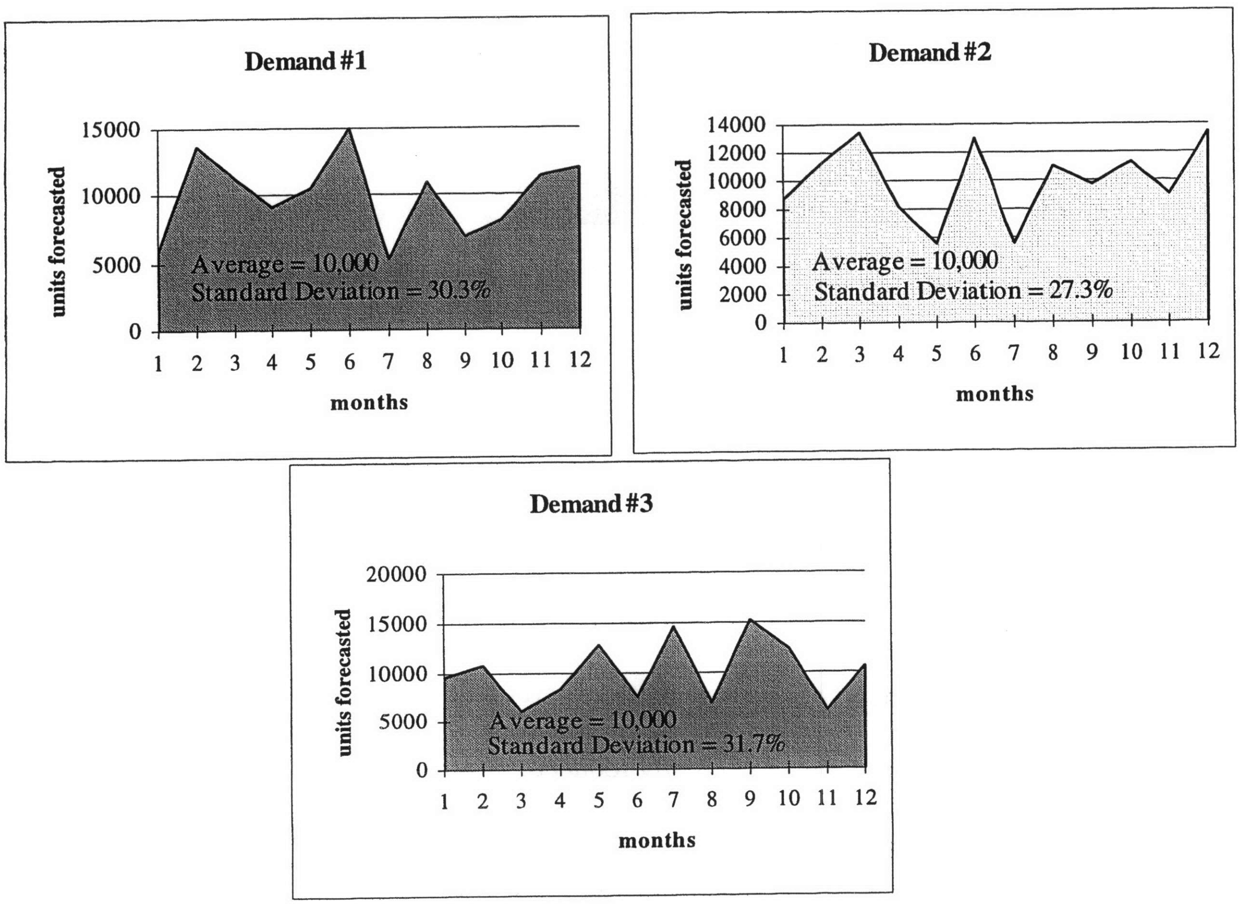

Figure 18 Example of demand variability

Notice that, even though the average inventory is 10,000 units, in order to compensate for fluctuating demand, a substantial amount of safety stock for each of the three components would have to be carried in order to compensate for this uncertainty.

If, however, two of the components were leveraged such that only one distinct part number would need to be carried, the fluctuations in demand would be dampened somewhat, as illustrated in the figure below.

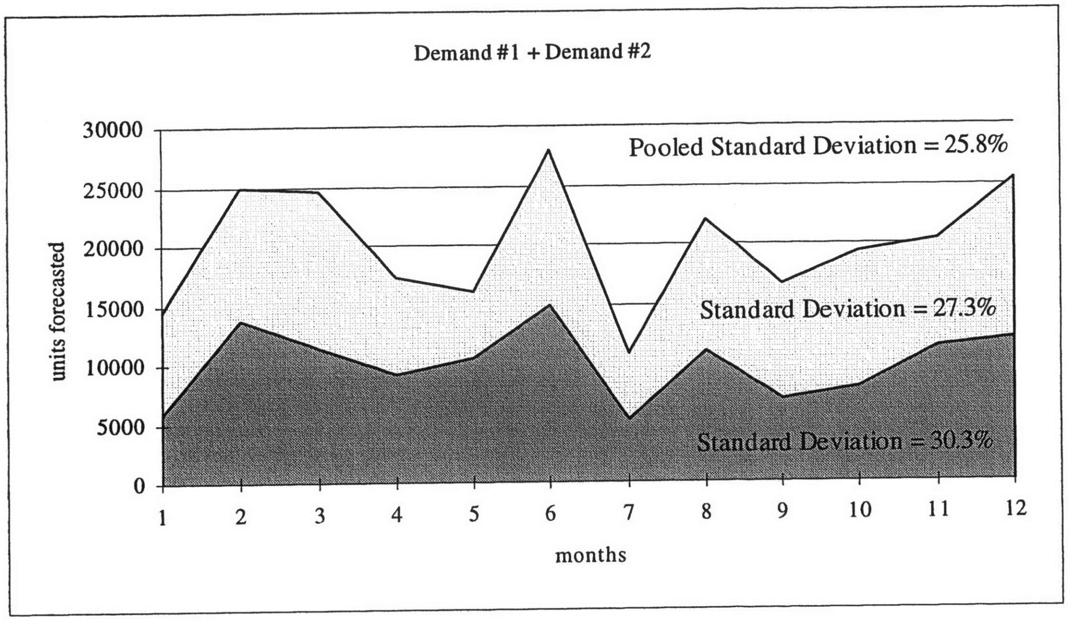

Figure 19 Effect of risk pooling two components on demand fluctuations

While the same amount of average inventory must be carried, 20,000 units, the fluctuations between the two separate demands help to cancel each other out. Thus, the pooled standard deviation is less than the two separate deviations. If we carry this exercise one step further, leveraging the three components so that one distinct part could satisfy all three demands, we see that the standard deviation of demand is greatly reduced, thus the amount of safety stock necessary to insure the desired service level is met can also be minimized.

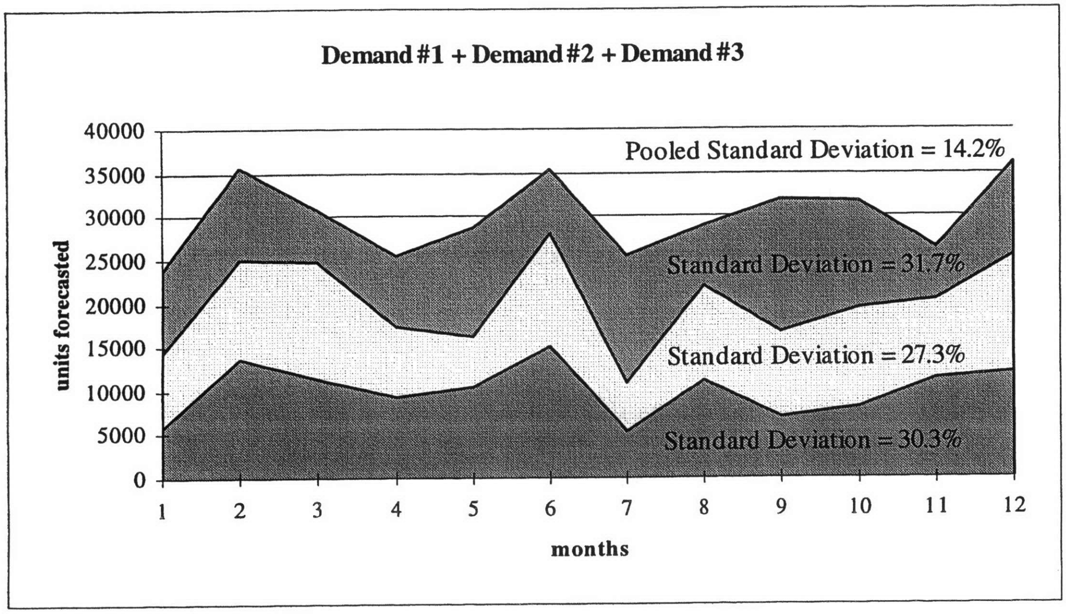

Figure 20 Effect of risk pooling three components on demand fluctuations

This exercise is in no way a criticism on the forecasting accuracy of components in Exeter, but it is a powerful illustration which sheds light on how inventory risk and holding can be reduced through additional platform leveraging of components.

What Did Not Hit the Radar: Other Considerations

What has been highlighted thus far are the major *cost* impact areas through use of uniquely designed components. What hasn't been mentioned are the areas effected through the use of unique components, which do not add significant cost to the system. One such area is in production. While actual manufacturing costs account for a large portion of cost of sales in many companies, it is not a significant area when looking at workstation cost at HP. The main reason for this is the efforts and improvements which have been focused on previously within WSY, particularly in their Exeter, New Hampshire facility. Through Design for Manufacturability efforts, line optimization, and an effort to reduce the number of sub-assemblies that go into a workstation which must be assembled at the Exeter Final Assembly and Systems Test (FAST) location, the actual assembly stage of the workstation takes less than thirty minutes, and accounts for less than 3% of the cost of the workstation. Thus, even a 50% improvement in manufacturing costs, which would take extreme effort, would only account for less than 2% of the total workstation cost. Similarly, efforts in test writing, which is where the major costs occur in the test process, would not significantly improve the cost of sales for the workstation. While the costs associated with these activities is not great, this does not imply that efforts for improvement are limited. One notable difficulty experienced by manufacturing in Exeter is the material that must be placed on the floor to support each distinct workstation family. The facility is designed so that all of the lines are flexible manufacturing lines, allowing any product to be built on any line. Similarly, any product may be tested at any one of the test bays; even mixed batches containing a full range of processors and platforms may be tested simultaneously within one test bay. It is not possible, however, to assemble more than one product family on any line at any time. As explained above, it should be technically feasible, but because of the amount of material that would have to be on the floor to support multiple families, there simply isn't space behind each line worker to hold the in-process inventory. Additionally, the amount of inventory which is unique to each family adds time line changes when transitioning from one family to another. The only modification which needs to occur to the line is a change to the inventory available to the operator (inventory from the previous platform taken away, stock replaced with inventory needed for the new platform). The more components which must be replaced, the longer this takes, and the higher the likelihood of damage to sensitive components (such as PCAs) due to increased handling. This problem multiplies itself as the product reaches its end of life. After the volume per day of a workstation platform drops down to 20 or less, the platform is moved into a separate, lower volume, job shop environment (AMMO). In this environment, multiple families are run down one line. The space necessary to hold this inventory is excessive. Additionally, there is more of a likelihood of wrong components being added to the system (they look the same and are right next to each other).

Another concern which doesn't hit the financial radar is the use of low cost, but uniquely designed, components within the workstation. A good example of this is the hardware. Since the hardware is uniquely designed, and usually designed to match only one product family, a risk is run to production continuity. If, for some reason, Exeter runs out of inventory on a uniquely designed screw, they cannot run down to the local hardware store, or get a rush order from a local hardware supplier to keep the line running. Instead, they must negotiate with their supplier, who needs to *make* the screws, then get them to the FAST facility. This may take two days or it may take four weeks. During this time, production on that particular family comes to a halt, holding potentially hundreds of thousands of dollars worth of inventory, increasing the manufacturing cycle time, decreasing their order delivery time, and most likely aggravating their customers. Why? For a custom-designed screw that costs no more that 15¢. As seen above, the 15¢ does not make a dent in the overall cost of the workstation, but does disrupt production continuity.

There are other areas which are not financially effected, but the increase in number of components, by not using platform leveraged components, adds complexity to the system. This complexity can be seen in the supply chain as well as in support functions such as documentation, planning, test, and purchasing. Additionally, there are hidden costs that are difficult to capture in the areas of assurance of supply, manufacturing space, channel complexity, world wide distribution, and time to market. If WSY were to move toward more industry standard components, operating profit, as well as infrastructure complexity, could be positively effected.

Chapter Summary

The bottom-line advantages to using either industry standard or platform leveraged components is significant, up to 10% and 4.2% of the system costs, respectively. By changing a few of the critical components, such as power supply, I/O PCAs, graphics or monitors, a significant portion of the costs could still be realized without changing all of the components. While the cost savings are significant, there are additional areas, such as end of life manufacturing (AMMO), which suffer from the proliferation of components but do not add enough cost to the system to warrant management's attention. In areas such as AMMO, test implementation, and small dollar value components, although the cost is minimal compared to larger costs, such as I/O PCA development, it should be recognized that improvements can be realized in these areas due to leveraging materials choices.

IV. CONCLUSIONS AND RECOMMENTATIONS

So, What Does This Mean?

The scenarios painted above are with respect to the lifetime costs incurred through custom designed components is in no way unique to the Workstation Systems Division of HP, or to Hewlett-Packard itself. Difficulties in resolving make versus buy decisions as components migrate toward an industry standard is seen in a variety of manufacturing companies (Prahalad, et. al., 1990). Compounding these difficulties is the possible clash between a well established company culture of believing that the best quality and performance of a component comes from one which is designed internally, and that nobody can do it better (Christensen, 1992). As the components progress towards a given standard, the competitive advantage offered to the system by the given component also decreases. This raises two key questions: (1) does the component continue to add competitive advantage? and (2) if the component does not add competitive advantage and if the company can do a better job of designing the component in house, is it worthwhile to market the component to other possible customers? In answering the first question, if the components do not add competitive advantage, a better strategy would be to focus on the components of the system which do add advantage and outsource the rest of the system. This will allow the company to reduce their internal costs, the material cost of the components, and to focus critical resources toward areas where big impacts can be realized. Not only will this aid the OEM financially, but may allow them to develop better relationships with their suppliers which could significantly boost their performance (Kumpe, 1988) through closer working relationships with suppliers who are making the biggest technological advances in their industry.

Addressing the second question, it is necessary to understand the competition, both the direct traditional competition of the company and competition from potential suppliers. If it is possible that the highest quality, best performance components are produced in house, the company could gain extra revenue by becoming a supplier of the commodity to their competitors.

An example of this last point can be seen in HP's former disk drive manufacturing division. As the formats and technical specifications of disk drives for the computer industry were approaching industry standards, it became clear that HP's drives were competitive to other drives available on the market. Thus, HP continued to build the drives, but in addition to supplying the drives to internal divisions, the drives were also sold to competitors. For a number of years, Hewlett-Packard enjoyed a comfortable market share and substantial gross margins on the sale of their drives. Once the drives had moved fully into a commodity status, where there was little to no differentiation between drives manufactured by various suppliers, and the basis of competition was on cost and distribution systems, HP realized that they no longer held an advantage by internally producing the drives. Therefore, the decision was made to close the disk drive division and to source the drives exclusively from outside suppliers. The decision, though against typical HP culture, was financially sound.

There are a number of components currently used in workstations which could benefit from the above example. As the cost of building a workstation steadily decreases, but does so at a rate far slower than the decrease in revenue generated per workstation, it is critical that these painful make versus buy decisions be addressed and clarified quickly. As there is a large amount of sunk cost in the workstation due to development time, development cost, tooling costs, etc., it does not make sense to re-design workstations which are typically offered to the public.

However, shifts in the mental model and performance metrics which guide the marketing and development teams throughout the creation of a new workstation platform must happen in order for HP to continue to be competitive over the next five to ten years.

In addition to the strict cost savings, the possibilities of increasing the price/performance of the workstations within a relatively short period of time is appealing. Also, the time savings in development and ramp to full volume manufacturing could offer a distinct advantage. Finally, benefits associated with leveraging materials could be substantial in risk pooling of material, ease of customer ordering, ease of platform management, manufacturing materials space, and channel complexity.

RECOMMENDATIONS FOR FURTHER ANALYSIS

In order to implement the ideas discussed above, a division wide commitment to reduce component costs would be needed. In order to facilitate this change, and to move forward with a design that satisfies HP's commitment to excellence in engineering design and at the same time reduce the cost of sales for future platforms, a cross-organizational team must be formed, comprised of members representing marketing, development, manufacturing, procurement, materials engineering, finance, test procedures, strategy, and new product introduction. To make it a fully functional team that takes advantage of concurrent engineering, participation between WSY and key suppliers should encourage representatives from the supply organizations to be present during the design phase, opening communication to ensure that HP's direction for future goals and product development align with the technical and strategic direction of high-dollar item components. This would not only increase communication during the design phase, but would also aid in reducing uniquely designed components, and hopefully bring the material cost even lower than the current quoted prices. Before product development begins, alignment of goals and metrics by members of the cross-organizational team should be defined in a way which maximizes the profitability and performance of each functional area, as well as by the division as a whole. Simplification guidelines must be produced to drive Design for Order Fulfillment criteria which will help achieve this goal. Additionally, work in the areas of concurrent engineering, Design for Supply Chain, and product simplification must be made, such that the technical competitiveness of the HP workstation does not suffer, but instead improves. Finally, use of platform leveraged or industry standard components for areas of the workstation that do not add competitive advantage must be universally accepted by all functional areas within WSY.

As changes to the structure of Hewlett-Packard take place, further refinement and tracking of critical costs and their true dependence on volume must be determined. Further investigation of failure rates, workstation life reliability, component reliability (incoming), component interconnect, component performance, inventory turn rate required for HP as an entity, inventory carrying cost required for HP as an entity must be investigated through the joint efforts of development, materials management, and strategic planning and modeling teams. Finally, further investigation into the cost savings possible throughout HP's complete workstation and server product lines through the use of industry standard or platform leveraged components would prove advantageous.

APPENDICES

RAW DATA RESULTS

		Current Cost			Leveraged cost			Industry standard cost		
	Volume	**Infra-structure costs**	**Component costs**	**Inventory costs**	**Infra-structure costs**	**Component costs**	**Inventory costs**	**Infra-structure costs**	**Component costs**	**Inventory costs**
complete systems	20000	$ 18,772,524			$ 15,515,085			$ 16,485,542		
Monitors	20000	$ 296,674	$ 25,673,895	$ 91,511	$ 296,674	$ 25,656,808	$ 915,113	$ 296,674	$ 25,656,808	$ 915,113
hard drives	18000	$ 340,405	$ 10,250,797	$ 216,298	$ 262,080	$ 9,513,190	$ 200,225	$ 131,301	$ 8,684,598	$ 191,041
floppy drives	5400	$ 570,116	$ 215,894	$ 14,547	$ 560,472	$ 213,173	$ 14,547	$ 165,540	$ 115,940	$ 8,265
CD ROM	4000	$ 805,611	$ 449,112	$ 51,862	$ 792,333	$ 448,706	$ 51,862	$ 249,327	$ 403,916	$ 35,204
DAT drive	1000	$ 1,489,264	$ 481,832	$ 210,641	$ 1,489,264	$ 481,731	$ 210,641	$ 630,395	$ 477,906	$ 210,641
chassis /mech assy	20000	$ 1,592,779	$ 14,737,460	$ 653,723	$ 1,140,532	$ 12,095,057	$ 517,966	$ 795,478	$ 11,947,606	$ 487,523
power supply	20000	$ 168,076	$ 4,072,204	$ 137,034	$ 113,890	$ 3,349,686	$ 113,606	$ 72,663	$ 1,976,018	$ 80,618
graphics	7800	$ 2,389,410	$ 16,290,148	$ 880,671	$ 2,304,844	$ 16,290,148	$ 880,671	$ 2,375,482	$ 16,290,148	$ 880,644
CPU	20000	$ 7,774,149	$ 82,517,560	$ 2,748,193	$ 7,594,524	$ 82,462,360	$ 2,748,193	$ 7,749,999	$ 82,462,360	$ 2,749,780
I/O	20000	$ 1,517,046	$ 31,662,490	$ 577,745	$ 1,181,812	$ 30,035,401	$ 432,205	$ 793,165	$ 28,857,358	$ 492,058
memory	26000	$ 827,998	$ 59,535,086	$ 784,068	$ 800,132	$ 59,524,621	$ 784,068	$ 434,027	$ 48,993,123	$ 666,458
hardware	20000	$ 10,883	$ 692,530	$ 20,063	$ 10,842	$ 692,530	$ 17,563	$ 9,678	$ 346,265	$ 9,439
labels / pkg.	20000	$ 69,430	$ 802,240	$ 44,749	$ 55,598	$ 168,130	$ 4,689	$ 55,954	$ 168,130	$ 13,319
cables/connect	20000	$ 10,692	$ 934,260	$ 24,596	$ 9,018	$ 934,260	$ 22,809	$ 36,157	$ 934,260	$ 22,581
totals		**$ 36,635,057**	**$ 248,315,507**	**$ 6,455,702**	**$ 32,127,098**	**$ 241,865,800**	**$ 6,914,159**	**$ 30,281,381**	**$ 227,314,436**	**$ 6,762,683**

RAW MODEL NUMBERS

Component	**Memory**	**Power supply**	**Mass storage**	**I/O PCAs**	**CPU**	**Chassis / Mech. Assembly**	**Monitor**	**Graphics**	**Labels / Pkg.**	**Cables / Conn.**	**Hard-ware**	**Totals**
Industry standard?	99%	no	no	no	no	no	no	no	mostly	N/A	99%	
Leveraged?	yes	yes	no	no	yes	no	no	yes	no	no	no	
% demand attributed to Apollo:	23.47%	18.64%	31.98%	21.42%	100.00%	57.68%	31.98%	16.07%	11.81%	71.92%	6.14%	
HP Infrastructure cost - as is												
Headcount costs												16,544,409
NPI engineering costs												-
DFX engineering costs												
PCA setup costs			22,801		41,122	71,300	68,403	11,460				372,000
Field engineering costs					145,919	253,000	80,907	40,667				520,494
SMO repair costs	236,628	73,501	185,350	33,580	790,267	5,001,498	584,766	382,318	9,388	59,505	5,323	7,782,536
CPE engineering costs												59,800
Initial Qualification costs												-
planning												-
test development / implementation	-	-	-	-	3,316	5,750	1,838	924	-	-	-	11,829
information/documentation												28,750
incoming material test	6,072	9,647	16,549	11,084	-	-	-	-	-	-	317	130,632
operator training - test	-	-	-	-	-	-	-	-	-	-	-	-
operator training - assembly	-	-	-	-	-	-	-	-	-	-	-	-
R&D / development	-	214,380	735,525	73,898	1,326,538	2,300,000	735,525	369,705	135	827	3,532	7,692,547
strategic procurement	53,973	42,876	36,776	24,632	66,326	115,000	36,776	18,485	1,358	8,270	1,412	792,384
material qualification	-	-	7,355	4,926	15,918	27,600	8,826	4,436	-	-	-	107,712
vendor qualification	-	-	-	-	-	-	-	-	-	-	-	-

Component	Memory	Power supply	Mass storage	I/O PCAs	CPU	Chassis / Mech. Assembly	Monitor	Graphics	Labels / Pkg.	Cables / Conn.	Hard-ware	Totals
HP Infrastructure cost - if industry standard												
Headcount costs												14,380,909
NPI engineering costs												-
DFX engineering costs												
PCA setup costs			22,80		41,122	71,300	-	-				135,224
Field engineering costs					132,653	230,000	73,552	36,970				473,176
SMO repair costs	236,628	61,627	160,351	24,629	790,267	5,001,498	481,669	277,456	8,183	46,029	5,323	7,510,871
CPE engineering costs												59,800
Initial Qualification costs												-
planning												-
test development/ implementation	-	-	-	-	2,653	4,600	735	369	-	-	-	8,358
information/documentation												28,750
incoming material test	6,072	9,647	16,549	11,084	-	-	16,549	8,318	-	-	317	155,500
operator training - test	-											-
operator training - assembly	-	-	-	-	-	-	-	-	-	-	-	-
R&D / development	-	42,876	147,105	12,316	1,326,538	2,300,000	147,105	73,941	135	827	353	4,437,694
strategic procurement	53,973	17,150	36,776	24,632	66,326	115,000	73,552	36,970	1,358	8,270	1,412	590,023
material qualification	-	-	-	-	15,918	27,600	-	-	-	-	-	43,518
vendor qualification	-	-	-	-	-	-	-	-	-	-	-	-

Component	Memory	Power supply	Mass storage	I/O PCAs	CPU	Chassis / Mech. Assembly	Monitor	Graphics	Labels / Pkg.	Cables / Conn.	Hard-ware	Totals
HP Infrastructure cost - if across platforms												
Headcount costs												14,299,886
NPI engineering costs												-
DFX engineering costs												
PCA setup costs			14,250		41,122	71,300	42,752	7,163				176,589
Field engineering costs					63,010	76,250	34,937	17,560				191,759
SMO repair costs	236,628	-	160,351	31,457	790,267	5,001,498	556,412	382,318	9,388	46,029	5,323	7,640,083
CPE engineering costs												37,375
Initial Qualification costs												-
planning												-
test development/ implementation	-	-	-	-	1,658	2,875	919	462	-	-	-	5,914
information/documentation												-
incoming material test	6,072	4,823	8,274	5,542	-	-	-	-	-	-	158	88,910
operator training - test	-											-
operator training - assembly	-	-	-	-	-	-	-	-	-	-	-	-
R&D / development	-	214,380	514,868	51,729	1,326,538	2,300,000	514,868	369,705	95	578	2,472	7,227,713
strategic procurement	53,973	42,876	25,743	17,243	66,326	115,000	25,743	18,485	1,358	8,270	989	762,505
material qualification	-	-	5,148	4,926	15,918	27,600	6,178	4,436	-	-	-	102,858
vendor qualification	-	-	-	-	-	-	-	-	-	-	-	-
Supplier cost - as is												
tooling		-	588,420	19,952					-	827	105	609,306
assurance of supply		-	-	-	-	-	-	-	-	-	-	-
delivery performance		-	-	-	-	-	-	-	-	-	-	-
risk to HP (costs HP must eat if production decreases)	1,002	23	66	22	-	-	-	-	-	-	-	1,148

Component	Memory	Power supply	Mass storage	I/O PCAs	CPU	Chassis / Mech. Assembly	Monitor	Graphics	Labels / Pkg.	Cables / Conn.	Hard-ware	Totals
Supplier cost - if industry standard												
tooling		-	411,894	-					-	827	-	412,721
assurance of supply		-	-	-	-	-	-	-	-	-	-	-
delivery performance		-	-	-	-	-	-	-	-	-	-	-
risk to HP (costs HP must eat if production decreases)	1,002	-	26	-	-	-	-	-	-	-	-	1,029
Supplier cost - if across platforms												
tooling		-	411,894	2,991					-	719	74	415,679
assurance of supply		-	-	-	-	-	-	-	-	-	-	-
delivery performance		-	-	-	-	-	-	-	-	-	-	-
risk to HP (costs HP must eat if production decreases)	1,002	23	66	20	-	-	-	-	-	-	-	1,146
Inventory holding cost - as is												
Review frequency (in wks)	1	1	1	1	1	1	1	1	1	1	1	
Shipment frequency (weeks between ships)	1.15	1.15	4.6	3.105	0.23	0.23	0.23	0.23	4.6	4.6	0.575	
demand	900.8	1133.9	661.0	986.8	366.5	211.4	661.0	1315.0	1789.5	293.9	3441.0	
stdev of demand	295.3	395.0	285.8	374.3	98.6	179.6	285.8	296.7	569.3	634.1	878.9	
Inventory value	1,906,486	450,622	1,361,922	285,487	1,834,732	5,725,403	1,203,636	1,633,475	41,798	93,227	51,242	15,165,215
Inventory holding (25% + 7% cost of capital of Inv. value)	91,511	216,298	653,722	137,033	880,671	2,748,193	577,745	784,067	20,062	44,748	24,596	6,455,701
Forecast error	21%	99%	41%	214%	72%	52%	109%	43%	12%	12%	12%	
Lead time (x-factory)	0	1.15	6.9	6.9	8.05	4.6	4.6	8.05	12.65	2.875	6.9	
Lead time (shipping)	5.75	1.15	4.6	4.6	1.15	0.69	0.69	1.15	1.15	0.575	2.3	
Stdev of lead time	1.15	1.05	1.24	1.52	0.87	0.97	0.60	0.65	0.97	0.49	0.95	
Minimum order quantity	80	10	30	2500	10	1	10	1	1	1	10	

Component	Memory	Power supply	Mass storage	I/O PCAs	CPU	Chassis / Mech. Assembly	Monitor	Graphics	Labels / Pkg.	Cables / Conn.	Hard-ware	Totals
Inventory holding cost - if industry standard												
Review frequency	1	1	1	1	1	1	1	1	1	1	1	
Shipment frequency	1.15	1.15	2.3	1.15	0.23	0.23	1.15	0.23	4.6	4.6	0.575	
demand	900.8	1133.9	661.0	986.8	366.5	211.4	661.0	1315.0	1789.5	293.9	3441.0	
stdev of demand	295.3	395.0	285.8	374.3	98.6	179.6	285.8	296.7	569.3	634.1	878.9	
Inventory value	1,906,486	398,001	1,015,672	167,954	1,834,675	5,728,709	1,025,121	1,388,453	19,666	27,748	47,044	
Inventory holding (25% + 7% cost of capital of Inv. value)	915,113	191,040	487,522	80,617	880,643	2,749,780	492,057	666,457	9,439	13,318	22,581	
Forecast error	21%	99%	41%	214%	72%	52%	109%	43%	12%	12%	12%	
Lead time (x-factory)	0	1.15	2.3	2.3	8.05	4.6	1.725	8.05	10.35	2.875	4.6	
Lead time (shipping)	5.75	1.15	4.6	4.6	1.15	0.69	1.15	1.15	1.15	0.575	2.3	
Stdev of lead time	1.15	1.05	1.15	0.92	0.87	0.98	0.46	0.65	0.98	0.49	0.81	
Minimum order quantity	80	10	60	60	10	1	60	1	1	1	100	
Inventory holding cost - if across platforms												
Review frequency	1	1	1	1	1	1	1	1	1	1	1	
Shipment frequency	1.15	1.15	4.6	3.105	0.23	0.23	0.23	0.23	4.6	4.6	0.575	
demand	900.8	1133.9	1322.0	1973.7	366.5	211.4	1322.0	1315.0	3579.1	293.9	6882.0	
stdev of demand	295.3	395.0	383.0	501.5	98.6	179.6	383.0	296.7	762.9	634.1	1177.7	
Inventory value	1,906,486	417,136	2,158,193	473,358	1,834,732	5,725,403	1,800,854	1,633,475	73,177	19,538	95,038	
Inventory holding (25% + 7% cost of capital of Inv. value)	915,113	200,225	517,966	113,605	880,671	2,748,193	432,204	784,067	17,562	4,689	22,809	
Forecast error	21.39%	98.97%	27.52%	143.69%	72.02%	51.83%	72.86%	42.66%	7.71%	7.71%	7.71%	
Lead time (x-factory)	0	1.15	6.9	6.9	8.05	4.6	4.6	8.05	12.65	2.875	6.9	
Lead time (shipping)	5.75	1.15	4.6	4.6	1.15	0.69	0.69	1.15	1.15	0.575	2.3	
Stdev of lead time	1.15	1.05	1.24	1.52	0.87	0.97	0.60	0.65	0.97	0.49	0.95	
Minimum order quantity	80	10	30	2500	10	1	1	10	1	1	10	

Component	Memory	Power supply	Mass storage	I/O PCAs	CPU	Chassis / Mech. Assembly	Monitor	Graphics	Labels / Pkg.	Cables / Conn.	Hard-ware	Totals
Quality cost - as is												
AFR (annual failure rate)	2.9%	0.7%	1.8%	0.9%	0.8%	5.0%	4.4%	3.6%	0.0%	0.0%	0.0%	
Quality cost - if industry standard												
AFR (annual failure rate)	2.9%	0.7%	1.8%	0.4%	0.8%	5.0%	0.3%	0.3%	0.0%	0.0%	0.0%	
Quality cost - if across platforms												
AFR (annual failure rate)	2.9%	0.7%	1.8%	0.9%	0.8%	5.0%	4.4%	3.6%	0.0%	0.0%	0.0%	
Material cost - as is												
component cost	1,002	541	664	150	2,070	3,924	1,512	2,208	34	40	46	
Material cost - if industry standard												
component cost	1,002	478	565	97	2,070	3,924	1,436	1,876	17	8	46	
Material cost - if across platforms												
component cost	1,002	501	565	135	2,070	3,924	1,436	2,208	34	8	46	
Transport cost - as is												
shipping cost - air	132	2	49	3	2	2	2	2	-	-	-	198
shipping cost - ocean	14	0.52	11	0.58					-	-	-	28
% ocean ship	99%	50%	46%	48%	0%	0%	0%	0%				
duty cost	22	-	-	-	-	-	-	-	-	-	-	22
Transport cost - if industry standard												
shipping cost - air	132	2	49	3	2	2	2	2	-	-	-	198
shipping cost - ocean	14	0.52	11	0.58	-	-	-	-	-	-	-	28
% ocean ship	100%	75%	100%	85%	0%	0%	0%	0%		0%		
duty cost	22	-	-	-	-	-	-	-	-	-	-	22

Component	Memory	Power supply	Mass storage	I/O PCAs	CPU	Chassis / Mech. Assembly	Monitor	Graphics	Labels / Pkg.	Cables / Conn.	Hard-ware	Totals
Transport cost - if across platforms												
shipping cost - air	132	2	49	3	2	2	2	2S	-	-	-	198
shipping cost - ocean	14	0.52	11	0.58	-	-	-	-	-	-	-	28
% ocean ship	100%	62%	100%	48%	0%	0%	0%	0%				
duty cost	22	-	-	-	-	-	-	-	-	-	-	22

ASSUMPTIONS – DETAILED

- Current connect rates used are: internal mass storage = 0.9, floppy drive = 0.27, CD ROM = 0.2, DAT drive = 0.05, graphics = 0.39, memory = 1.3, all else = 1.
- Volume for life of product based on volume over next 6 month period, 1 year volume estimate for all same-class workstations, and average production life of 18 months.
- Percentage of infrastructure allocated to Apollo 260 is based on projected volume.
- Percentage of component costs allocated to the Apollo 260 is based on the demand for each part number divided by the demand of the Apollo 260 CPU.
- Inventory holding = 25% + 7% cost of capital
- R&D savings percentages if platform leveraged = 60% of the cost of the two platforms. Thus, savings per platform are assumed to be 30%.
- Demand is calculated from projected weekly usage for the next three months (taken from the current MRP). These values reflect the average weekly usage plan for the part (not the product) to accurately determine standard deviation in demand.
- Cost of warranty is ignored in this analysis since it is measured as a percentage of revenue (2% of revenue). It is unclear how this would change if shifted to industry standard parts.
- Defect cost is accounted for in the SMO costs.
- In any scenario, the suppliers currently used would remain the same, or would be from the same part of the world, so that shipping costs and transportation lead times would remain constant.
- Strategic Procurement has a range from $23,000 to $34,500 based on historical costs.
- Safety qualification costs for component must be paid for in all scenarios. Internal qualifications would still need to occur even if industry standard parts were used, to insure proper interplay between components.
- Material qualification costs are based on cost per prototype for 4 prototypes.
- The risk cost to HP from the supplier in the use of uniquely designed components which are not leveraged across platforms is calculated to be the cost HP incurs for the supplier to retrofit or scrap the material multiplied by the forecast error and decreasing volume over a 2 month period.
- All commodities are reviewed by the buyers once per week.
- Shipment frequencies are based on conversations with buyers, MRP demand, and supplier minimum order quantities.
- In leveraged scenarios, demand would double, assuming the second platform would have equal volume to the Apollo 260.
- Forecasting error would reduce in platform leveraged scenarios for components which were not previously leveraged.
- AFR rates are kept constant in industry standard and platform leveraged scenarios where the major functional components of an assembly are currently industry standard, but connections, hardware, or packaging cause the component to be non-industry standard or non-leveraged.
- Component costs are based off of April 1, 1996 purchasing price.
- Forecast errors are based off of monthly forecast error over the last 12 months, divided by sqrt(4.3) to determine the weekly forecast error.
- Lead time standard deviation is based off of deviation of number of shipments over a 12 month period, reported in weeks.

Detailed Numbers: Industry Standard Power Supply

Costs	Current	With change to Industry Standard	% Savings
Material	$1445	$1105	7%
Inventory Holding	$2,146,857	$429,371	80%
Initial Qualification	$493,908	$478,883	3%
Test Development	$0	$0	0%
SMO & field Engineering	$589,956	$541,758	10%
Strategic Procurement	$96,608	$0	100%

Detailed Numbers: Industry Standard Mass Storage

Costs	Current	With change to Industry Standard	% Savings
Material	$665	$565	15%
Inventory Holding	$735,526	$147,105	80%
Initial Qualification	$185,350	$160,351	12%
Test Development	$588,421	$411,894	30%
SMO & field Engineering	$670,271	$504,071	25%
Strategic Procurement	$7,355	$0	100%

Detailed Numbers: Platform Leveraged Mass Storage

Costs	Current	With change to Platform Leveraged	% Savings
Material	$665	$565	15%
Inventory Holding	$735,526	$514,868	30%
Initial Qualification	$185,350	$160,351	23%
Test Development	$588,421	$411,894	30%
SMO & field Engineering	$670,271	$526,241	21%
Strategic Procurement	$7,355	$0	100%

Detailed Numbers: Platform Leveraged I/O

Costs	Current	With change to Platform Leveraged	% Savings
Material	$150	$135	10%
Inventory Holding	$73,899	$51,729	30%
Initial Qualification	$33,580	$31,457	6%
Test Development	$19,952	$2,991	95%
SMO & field Engineering	$148,118	$119,148	18%
Strategic Procurement	$4,927	$4,927	0%

Detailed Numbers: Industry Standard Monitor

Costs	Current	With change to Industry Standard	% Savings
Material	$1,512	$1,436	5%
Inventory Holding	$735,526	$147,105	80%
Initial Qualification	$584,777	$481,670	17%
Test Development	$68,404	$0	100%
SMO & field Engineering	$577,745	$508,607	16%
Strategic Procurement	$8,826	$0	100%

Detailed Numbers: Platform Leveraged Monitor

Costs	Current	With change to Platform Leveraged	% Savings
Material	$1,512	$1,436	5%
Inventory Holding	$735,526	$514,868	30%
Initial Qualification	$584,777	$556,412	11%
Test Development	$68,404	$42,752	38%
SMO & field Engineering	$577,745	$432,205	26%
Strategic Procurement	$8,826	$6,178	30%

Detailed Numbers: Industry Standard Graphics

Costs	Current	With change to Industry Standard	% Savings
Material	$2,208	$1,877	15%
Inventory Holding	$369,705	$73,941	80%
Initial Qualification	$382,318	$277,456	26%
Test Development	$11,461	$0	100%
SMO & field Engineering	$788,504	$674,776	15%
Strategic Procurement	$4,436	$0	100%

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