Dynamic Pricing Effects on Strategic Sourcing and Supplier Relations

Nathan Smith

BS Electrical Engineering, Brigham Young University

Submitted to the Sloan School of Management and
the Department of Electrical Engineering and Computer Science
in Partial Fulfillment of the Requirements for the Degrees of
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Signature of Author.......................................
Sloan School of Management
Department of Electrical Engineering and Computer Science
May 10, 2002

Certified by ....
Charles Fine
Professor of Management, Sloan School of Management
Thesis Advisor

Certified by ....
Steven B. Leeb
Associate Professor of Electrical Engineering and Computer Science
Thesis Advisor

Approved by...
Margaret Andrews
Executive Director of Master's Program
Sloan School of Management

Approved by...
Arthur C. Smith, Director
Committee for Graduate Students
Department of Electrical Engineering and Computer Science

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Abstract

Sun Microsystems, a leading manufacturer of computer servers, leverages the knowledge and capacity of numerous suppliers to design and build its leading-edge servers. Sun must continually balance supplier relations with cost-cutting measures to achieve competitive products and pricing. To lower its direct material spend, Sun has pursued a form of reverse auctions internally called dynamic bidding (DBs).

With average savings of approximately 20% over historical pricing, dynamic bidding proved to be a powerful tool for Sun to reduce direct materials cost. While pleased with the savings, Sun desired additional research to understand the long-term ramifications and industry's acceptance of the model to verify this was a valid strategic vision for the company going forward.

This thesis provides research into the long-term effects of dynamic bidding at Sun. The results are gathered from academic research, industry benchmarking, and statistical analysis on prior events. The research indicates dynamic bidding is a valuable process for Sun and the implementation method Sun uses is effective. However, it also reveals that dynamic bidding increases the strain on supplier relations and requires the proper framework to be successful.

For long-term supplier acceptance, suppliers need to understand the nature of their relationship with Sun. This requires a new level of strategic planning. The stability of specification, use of contracts, and the communication of product life cycle expectations are vital components to create the proper framework for dynamic bidding to be successful. Bidding is a significant deviation from Sun's historic sourcing process. The new process strains relations during the transition from previous methods to bidding. The strain can be minimized though effective planning and communication. Industry acceptance and internal integrity to the defined process will play a role in the continued success of bidding.

Thesis Advisor: Charles Fine
Title: Professor of Sloan School of Management

Thesis Advisor: Steven B. Leeb
Title: Associate Professor of Electrical and Computer Engineering

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He also wishes to acknowledge the unfailing support of his wife Sarah and her willingness to carry the difficult burden of caring for three children single-handedly to allow the author to work uninterrupted on this thesis.

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1 INTRODUCTION

1.1 Background on Sun Microsystems

Sun Microsystems, Inc was founded in 1982 by Scott McNealy, Bill Joy, Andreas Bechtolsheim, and Vinod Khosla in Palo Alto, California. Since its beginning, Sun (which derived its name from the Stanford University Network) has pushed its single vision forward: "The Network is the Computer"™. Sun's first computer included a TCP/IP connection for networking and employees have used email from day one. From its beginning, Sun has been a pioneer in network computing.

Sun experienced rapid growth through the eighties and nineties, fueled by the rapid expansion of the Internet and increasing demand for high-powered, reliable servers. Today, Sun employs over 40,000 employees and has a global presence. Annual revenue reached 17.6 billion in 2001. Scott McNealy is the current CEO and continues to provide a forward-looking vision for Sun.

Sun has an extensive product line offering multi-million dollar high-end servers, mid- and low-end servers, workstations and data storage systems. Sun also sells software, most notably, Solaris and Java. All of Sun's hardware products are based on the SPARC microprocessor and all use Sun's version of Unix, Solaris.

Sun believes part of their competitive advantage is providing their customers with a single point for customer service. If something goes wrong with a Sun computer, customers know where to go to resolve the problem. Sun believes this consistency is one of the reasons they are the number one shipper of Unix systems in the world.[1]

Sun's primary competitors in hardware are IBM, Compaq, HP and Dell. With Sun's recent entry into storage devices, EMC has also become a competitor. In software, Microsoft is Sun's principle competitor.

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[1] IDC Worldwide Server Tracker, 3QCY01, Dec 2001

Sun has based their external strategy on three principles they refer to as their "three big bets" as outlined below[2]:

- Massive Scalability- The ability to scale the bandwidth, processing power, and storage capacity of servers to meet the demands of the net economy.
- Continuous real-time access- Design software, build systems, and provide support services that eliminate downtime and deliver real-time responsiveness enabling people to have continuous access to the Net.
- Integratable stack- Create an integrated hardware and software stack for the backend network where the microprocessors, storage, system software, and middleware are all seamlessly integrated.

Sun uses an outsourced manufacturing strategy. They retain most of the design work in-house and use external manufacturers to build and integrate the hardware. Sun maintains direct sourcing ownership of core parts such as the SPARC microprocessor, and critical parts such as the enclosure and boards used in their systems. They allow the external manufacturers to source non-critical components such as resistors from Sun-approved suppliers. Figure 1-1 shows the basic flow of information and material within Sun's supply chain. Sun works hard to maintain strong relations with their core supply base while continuing to provide innovative, cost effective solutions to their complex sourcing needs.

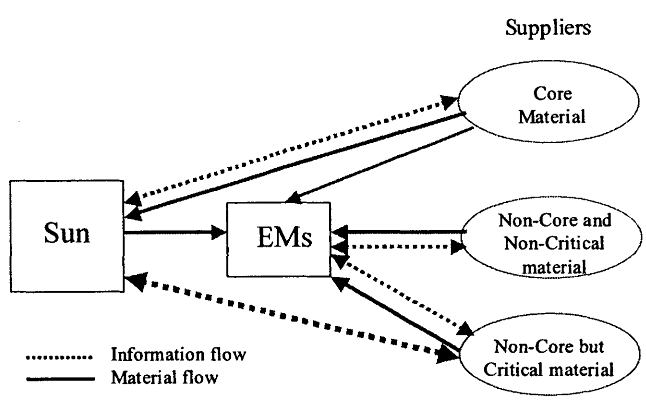

Figure 1-1: Sun's Supply Chain Model

[2]Ed Zander, THREE BIG BETS, http://www.sun.com/dot-com/perspectives/threebets.html

1.2 Background on Reverse Auctions

The emergence of the Internet and the pace of technological advancement have created opportunities for new paradigms in supply chain design and e-commerce. Reverse auctions are one of many initiatives that companies are using to control product costs and improve overall supply chain efficiencies. Reverse auction adoption has increased in use from nearly non-existent six years ago to approximately a third of companies using some form today with estimates of over 50% adoption within a year[3]

A reverse auction is an event similar to a conventional forward auction in that it is an attempt to identify the true open market value for a good or service. However, unlike a forward auction where a single seller is attempting to sell a good or service to the highest bidder of multiple buyers, a reverse auction has a single buyer attempting to purchase a good or service from the lowest bidder among multiple suppliers. (see Figure 1-2) Suppliers successively lower their bids during the event in an attempt to secure the opportunity to supply goods or services to the buyer.

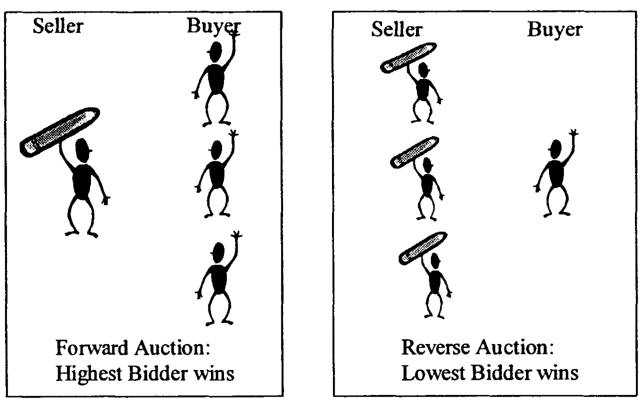

Figure 1-2: Forward vs. Reverse Auctions

While the concept of a reverse auction predates the Internet boom[4], it was inefficient due to the complexities of gathering multiple suppliers to a single location. The emergence of the web has made conducting a real-time online auction with suppliers from around the world a practical reality. Auctions have grown rapidly in popularity because they offer

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[3] “Realizing the Vision of B2B Procurement”, Deloitte Consulting, , Jun 2001, pg 12
[4] Kasturi Rangan, “Freemarkets OnLine”, HBS 9-598-109, Feb 1999, pg. 2

buyers a tool to achieve real market pricing on goods and services in a matter of hours. Companies report average savings of 10% to 20%[5] over their historic costs with some items reaching over 80% savings over historic pricing. The return on investment is easy to calculate and the savings are immediate.

A host of start-ups and bellwether service/technology companies are racing to provide the technology and services to provide reverse auctions. The market of auctions providers is fragmented into numerous niche players, each pushing to gain controlling market share. There are three main variables that these auction providers adjust to capture their markets[6].

1. Full vs. Self Serve- A full serve auction provider guides buyers through the entire auction process. They suggest new suppliers and help generate the Request for Quotation (RFQ). They insure market integrity and provide training for both the buyers and suppliers. In contrast, a self-serve auction provider provides the software to run an auction but offers very limited training or other services.

2. Public vs Private Marketplace- The type of marketplace refers to how suppliers and buyers meet together to set-up auction events. A public marketplace is generally focused on a commodity or industry and any related buyer or seller can enter the site to set up events. Covisent is an example of a public exchange centered on the automotive industry. A private marketplace is where only invited participants can enter the site. GE's marketplace would be an example of a private market where only GE and GE's suppliers are invited to participate[7]. The type of marketplace used to select participants does not affect the format of the reverse auction.

3. Revenue Models- The other major variable in how auction providers are organized centers around their revenue stream. There are three basic models.

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[5] Anne Millen Porter, "E-Auctions: When to play, how to play, how to win", Purchasing.com, 2001, pg 10
[6] Kimberly McConnell, White Paper on Dynamic Bidding Supplier, 2001 (See Sun for Document)
[7] Sam Jaffe, "America's Future, Smart Globalization", Business Week Online, Aug 27, 2001

- **Subscription Fee-** A periodic flat fee paid regardless of the number of transactions performed during that time period.
- **Transaction Fee-** A fee paid for each transaction often based on a percent of the value of that transaction
- **License Fee-** A one-time up-front fee for the ownership of the software license. (upgrades are typically not included)

Freemarkets is the current leading auction provider. They are a full service provider that creates private marketplaces for its customers. Freemarkets is venturing into self-serve with their Quicksource software. Procuri is one of the leading Self-serve provider. Other significant players in the industry are Websphere offered by IBM, B2E Markets, Commerce One, GE Exchange offered by GE, Ariba, and Iplanet.

1.3 Background on the Thesis Problem

The design and manufacturing of a server is a complex task that requires thousands of man-years to complete. Sun leverages the knowledge and capacity of suppliers in its efforts to design and build leading edge servers. They utilize an outsourced manufacturing model retaining most of the design in-house. This split of design and manufacturing creates challenges for Sun to manage their supplier relations. They must achieve the proper balance between collaborating with suppliers to produce superior designs and negotiating with suppliers to lower their cost.

With the collapse of dot.coms and the decline in network infrastructure buildup that set the pace through most of the 90's, the demand for servers has softened. There are new low cost competitors entering the market.[8] Linux and WindowsNT™ based systems have captured over 50% of the market share[9]. In this new environment, Sun is looking for ways to trim cost without sacrificing the quality and performance.

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[8] Deborah Durham-Vichr, "Computers- Let the price war begin", NewsFactor Network, May 2001
[9] Mark Rosenberg,, Brian Silverman, "Sun Microsystems Inc: Solaris Strategy", HBS 9-701-058, Feb 2001, pg. 14.

One of the mechanisms Sun has pursued to lower the cost of direct material spending is a form of reverse auctions internally called Dynamic Bidding (DBs). Sun has aggressively pursued the use of dynamic bidding for direct materials. In their fiscal year 2001 they conducted over 40 auctions resulting in sourcing decisions for over $1 Billion USD. The preliminary use of dynamic bidding at Sun produced average savings of over 20% where the formula used to calculate savings is:

$$C_s = E_p - A_p - S_c - T_c$$

Where C_s *is the calculated savings from the bidding event*

E_p *is the expected (or previous) price*

A_p *is the actual price from the bidding event*

S_c *is the switching cost*

T_c *is the transaction cost*

While Sun had seen significant savings from reverse auctions, there was concern within Sun regarding the long-term and intangible costs that were not including in this formula to calculate savings. Management at Sun wanted additional information regarding the long-term effects of reverse auctions. The existing research in the academic and business world regarding the value of reverse auctions was very mixed.

1.3.1 Previous Academic Research on Supplier Relations Impact

Online reverse auctions have only been in broad use for the past three years. United Technology Corporation (UTC), one of the first movers in the industry, began six years ago.[10] Researchers are interested in studying reverse auctions, but data is still limited. There is no consensus among the academic community pertaining to the long-term implications of using reverse auctions.

Sandy Jap of the Goizueta Business School at Emory University conducted a research project in conjunction with the EBusiness@MIT Center, Leaders for

[10] Tim Reason, "Looking for Raw Deals", http://www.ecfonet.com/articles/al_looking_for_raw_deals.html, Jan 2001

Manufacturing Program, and MIT-Ford Alliance to analyze the impact of reverse auctions to supplier relations[11]. She looked at statistically significant variations between supplier sentiment before and after reverse-auction events and before and after sealed-bid events. Her conclusions indicated that the supplier's fear of opportunistic behavior from the buyer increases due to reverse auctions. Suppliers also showed an increased willingness to provide dedicated investment to buyers, presumably to gain a lock-in mechanism to avoid future reverse auction events. Her conclusions are based on statistical analysis, however her data set was limited.

Jan Tribiahn and Will Harman from Warwick Business School concluded from their study of six European automotive assemblers[12] that there is a perception that:

- supplier relations are damaged by reverse auctions
- price reductions come at the cost of quality to total cost
- auctions don't work for complex parts

However, their research showed that these objections can be overcome. The problems stem from a lack of understanding. Supplier relations and auctions are not mutually exclusive.

Bob Emiliani and Dave Stec from Rennselaer Polytechnic Institute and the Lally School for Business have studied the erosion of auction savings[13] and the use of contracts[14] with reverse auctions. They concluded that auctions do not deliver on intended results. Bob Emiliani stated regarding reverse auctions: "We've highlighted what could be benefits for both parties but the reality is that most of the benefit accrues to the buyer and the seller doesn't have a lot to gain... It's a way to compel your suppliers to reduce their prices. The

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[11] Sandy Jap, *The impact of Online, Reverse Auctions on Buyer-Supplier Relations*, July 2001
[12] Will Harman and Jan Tribiahn, *Overcoming the Challenges of Implementing Reverse Auctions*, July 2001
[13] Bob Emiliani and Dave Stec, *Realizing savings from Reverse Auctions*, Supply Chain Management Vol 7, 2002, pp. 12-23.
[14] Bob Emiliani and Dave Stec, *Online Reverse Auction Purchasing Contracts*, Supply Chain Management, Vol 6, 2001, pp 101-105.

gross savings number is a huge seductive figure for the executives...They are ravenous over this thing, but they haven't thought through it."[15]

In addition to these results, there are numerous ongoing academic research projects on reverse auctions. It is still an emerging field and results depend on implementation. It will take time before enough data can be gather to form consistent conclusions.

1.3.2 Industry Comments on Supplier Relations Impact

The opinion across industry, like academia, is mixed. The excerpts in Table 1-1 are taken from current news articles and provide a cross section of industry thought on reverse auctions. Most firms included in this research believed reverse auctions provide savings yet pose a risk to supplier relations. How companies interpret and evaluate the risk and benefits varies, as does their use of auctions.

Table 1-1: Industry Quotes regarding Reverse Auctions*

Manager	Company	Quote
Michael Mendoza, Global e-procurement leader	Owens Corning	"by and large supplier think it is a fair process"[16]
Dave Nelson, VP of world wide supply management	John Deere	"the reverse auction can be highly misused. There has to be a delicate balance"[17]
Lee Garbowitz, Director of corporate initiatives	General Electric	"We... educate [suppliers]...and make it clear that no matter what, this is the future for GE."[18]
Dick Hunter, Vice President for fulfillment and supply-chain management	Dell Computer	"For 'commoditized' [products]...the auctions worked great, however, for more 'customized' products, auctions were not effective."[19]

[15] Jim Ericson, "Reverse Auctions: Bad Idea?", Line56, Sept 20, 2001
[16] Demir Barlas, "Owens Corning Saves on Sourcing", Line56, July 11, 2001
[17] Jim Ericson, "Reverse Auctions: Bad Idea?", Line56, Sept 20, 2001
[18] Sam Jaffe, "America's Future, Smart Globalization", Business Week Online, Aug 27, 2001
[19] John H. Sheridan, "Proceed with Caution", Industry Week, Feb 12, 2001

1.3.3 Definition of the Thesis Problem

Given the broad variation in both industry and academia regarding reverse auctions, the purpose of this thesis is determine under what conditions the use of dynamic bidding is likely to be sustainable and successful in both cost savings and positive supplier relations for Sun Microsystems. The purpose of this thesis is not to conclusively determine the long-term effects on supplier relations due to reverse auctions. Such relationships evolve over an extended period of time and include many parameters beyond the scope of this thesis.

1.3.4 Outline of Thesis Report

This thesis is broken into seven remaining chapters.

Chapter 2: This chapter contains a technical analysis of the SunFire™ V880 server. To understand the supply chain decisions facing Sun, the reader needs a basic knowledge of Sun products and some of the challenges in designing them. A server is the combination of a wide range of products ranging from commodity nuts and bolts to complex processors. How all of these parts come together and interact plays a role in how Sun designs and manages their supply chain. To understand how reverse auctions will effect Sun, an understanding of these requirements is needed. The chapter will look at the different sub-systems (called commodity groups) within a server and how they are designed and sourced.

Chapter 3: Building on the basic understanding of what goes into building a Sun server, this chapter will move into how dynamic bidding fits into the picture. It will detail how dynamic bidding has been implemented at Sun including many of the best practices that have been identified from both statistical data and antidotal evidence from past bidding events.

Chapter 4: This chapter defines supplier relations and looks at the results Sun has seen from past events and predicts the impact to supplier relations assuming no changes are made .

Chapter 5: This chapter uses the results from Chapter 4 along with data gathered from interviews to determine what are non-quantifiable factors that appear to impact dynamic bidding. The factors fall into two categories, internal factors and external factors. Each is looked at in detail in this chapter.

Chapter 6: This chapter is the heart of the thesis. It will first look at some potential problems with how sourcing decisions are currently made within Sun. It will then present a model to determine the best methods for sourcing the various parts of the server. The suggested methods include dynamic bidding but are not limited to auctions. Each of the components of the model will be explained along with the data supporting the model. The model is meant to create a common framework for decision makers and to highlight vital trade-offs that must be made. The model is not meant to be a rigid formula for designing supply chains.

Chapter 7: Understanding how to position the tool and use it effectively does not guarantee that it will produce the desired results in the long run. Another major factor in the long-term viability of reverse auctions is how industry as a whole accepts them. Auctions are a popular trend right now. However, if industry does not accept them as a standard business practice, there could be a significant backlash against auctions driven by suppliers. This chapter looks at the current trends in auction adoption to predict if they are a passing fad or a lasting business practice.

Chapter 8: The final chapter in this thesis is the conclusion.

2 TECHNICAL ANALYSIS OF THE SUNFIRE™ V880 SERVER

The use of computers has become ubiquitous in the modern world. While the general population is aware of what a computer is and how it works from a user perspective, the details of what is inside the computer and how the many different parts work together is much less understood. This level of detail is needed to understand the complex process of sourcing the parts used to build computers. This chapter starts with a brief background on servers comprising of a quick summary of the general components of a computer and design considerations common in servers. It will then discuss the technical details of the SunFire™ V880 server and the components that make up this server. This information will provide a useful framework for understanding the design and implementation of supply chains at Sun.

2.1 Background on Servers

The server-class computers of today derive their name from the client/server network architecture derived in Xerox PARC in the early 80's.[20] The client/server model is based on distributed computing systems (clients) that run local versions of software connected to central repositories of data and information (servers). A server is simply a computer dedicated to serving a single task such as storing files (file server), managing printing (print server) or controlling network traffic (network server). Any computer can be used as a server. However, with the increasing demand for processing power and reliability, a server computer today typically refers to a class of computers defined by high I/O bandwidth, massive processing power, and exceptional reliability, availability, and serviceability (RAS).

The basic architecture of a server is similar to those found in any other computer systems [See Appendix A for more information on the basic architecture of computers]. The core of the server system is the microprocessor(s). Servers often use more than one microprocessor within the system; some of the larger systems integrate over 100

[20] http://www.parc.xerox.com/history.html

microprocessors.[21] The processors are connected together and to local random access memory (RAM) using complex circuit boards that implement either bus-based or switch-based interconnection protocols. Due to the high bandwidth requirements, many servers use the more complex switch-based protocols such as the crossbar switch or a non-uniform memory access (NUMA) switch. The processor and memory are connected to other devices and to the network through industry-standard protocols and interfaces. The storage devices (harddrives) are connected using Fibre Channel, Infiniband, SCSI or Gigabit Ethernet connections. The harddrives can be either local to the server or remote. Other I/O devices, such as graphic cards, modems, keyboards, and mice and network access can be connected to the server through multiple PCI slots, USB ports and Ethernet connections. For a more detailed explanation of the protocol used in servers, refer to Appendix B.

One of the central features of a server is its level of RAS. Servers are used in applications where downtime due to system failures and maintenance can cost millions of dollars in revenue.[22] To insure maximum availability, servers utilize redundant internal systems and self-monitoring hardware. The most common use of redundant systems is in the power supplies and cooling units which use a N+1 redundant configuration. However diskdrives, CPU boards, PCI cards and memory can also be configured for redundancy. To improve maintenance and service uptime, many of these systems also allow hot-swapping of hardware to replace parts without powering down the entire system. The design of reliability features significantly increases the complexity and cost of servers. A low-end server typically starts around $4000 USD with high-end servers costing over $4 million USD.[23] For more information regarding how redundant systems are implemented in servers, see Appendix B.

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[21] http://www.sun.com/servers/highend/sunfire15k/
[22] http://www.sun.com/smi/Press/sunflash/2002-02/sunflash.20020204.1.html
[23] http://store.sun.com/catalog/doc/BrowsePage.jhtml?catid=26829&catfocus=Servers

2.2 The Sun Fire™ V880 Server

Sun Microsystem's Sun Fire™ V880 server is a middle end-server targeted at running databases, e-commerce, or enterprise resource planning (ERP) applications. It features between two to eight UltraSPARC™ III processors, up to 32 GB of main memory (4 GB per processor), and a maximum of 12 drives of up to 72.8 GB each connected with a Fibre Channel disk subsystem. There are three PCI buses that can support up to 9 PCI devices: two at 66 MHz and seven at 33 MHz, all 64 bits wide. It supports Gigabit Ethernet and 10/100-BaseT Ethernet connections and has two USB ports for a keyboard and mouse. The system is controlled through the Solaris™ 8 operating system.[24]

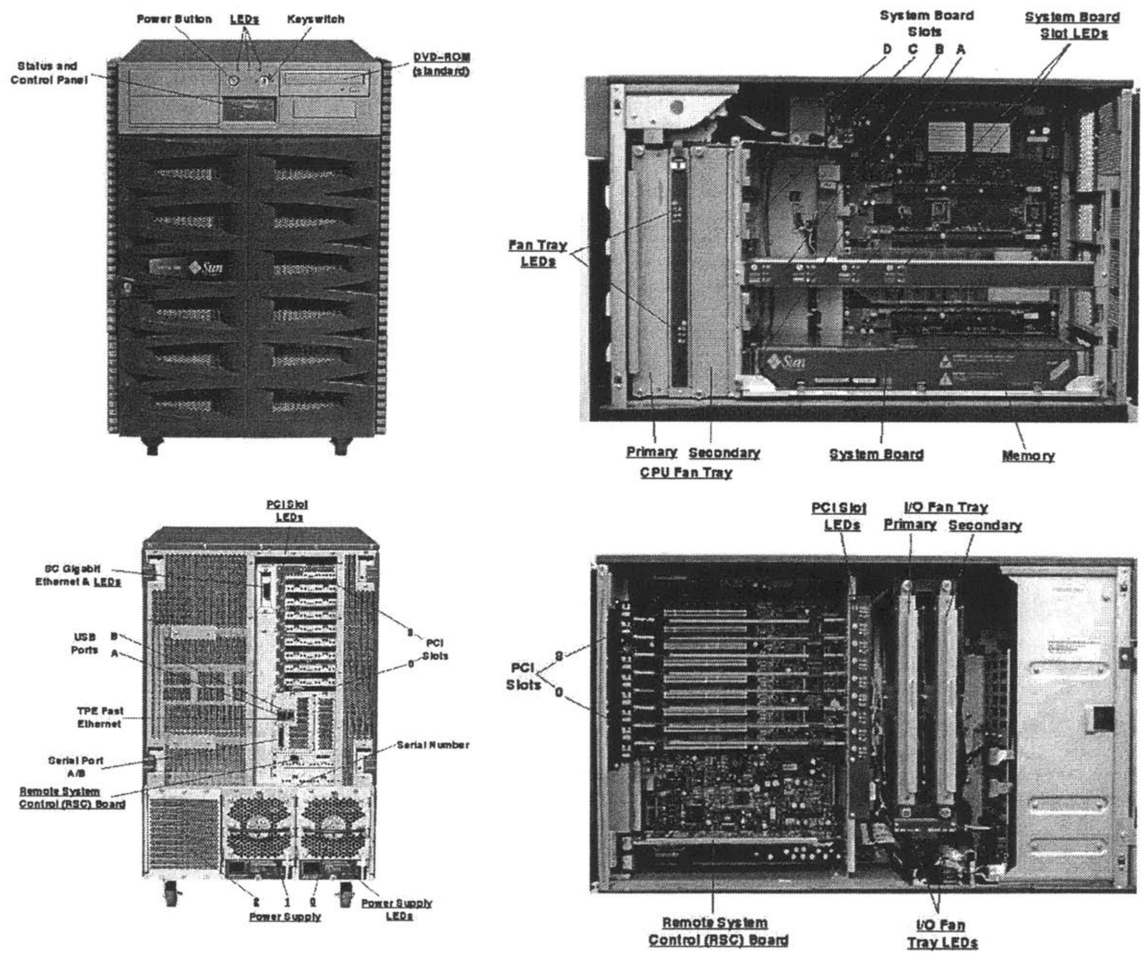

Figure 2-1: SunFire™ V880 Server

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[24] SunFire™ V880 Server System Architecture White Paper, Sun Microsystems Inc., Oct 2001

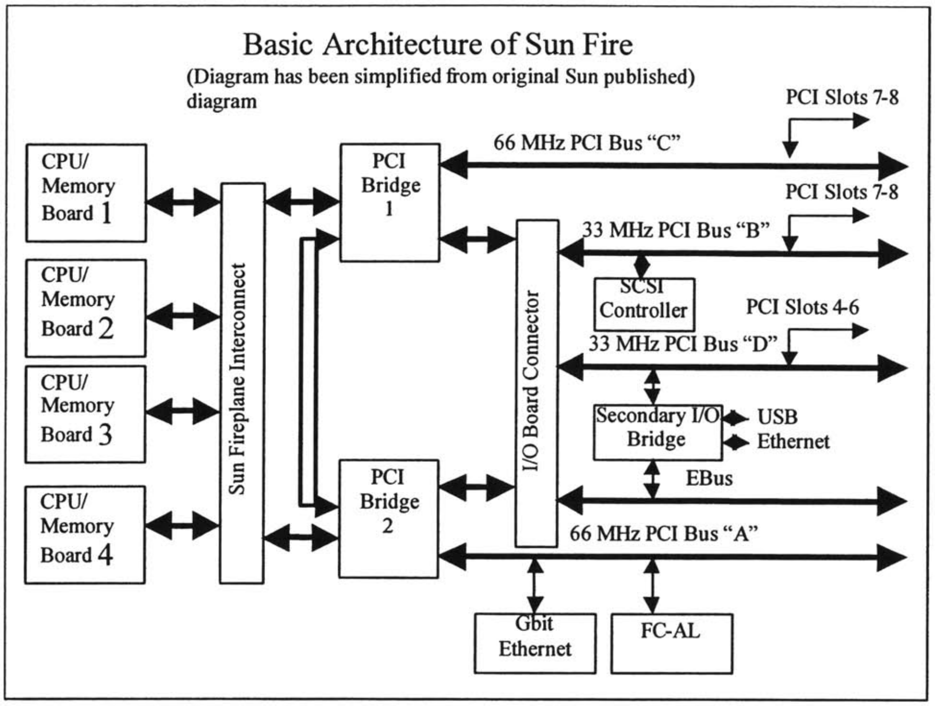

Figure 2-2: SunFire™ V880 Architecture

The following section will look at the architecture and design of the SunFire™ V880 server as an example of a typical server. The block diagram in Figure 2-2 outlines the basic architecture of the server and highlights the main components of the computer hardware including: the processor, Fireplane™ interconnect, PCI slots, FC-AL Disk control and network connections. The power and cooling units will also be considered.

2.2.1 UltraSPARC™ III Processor

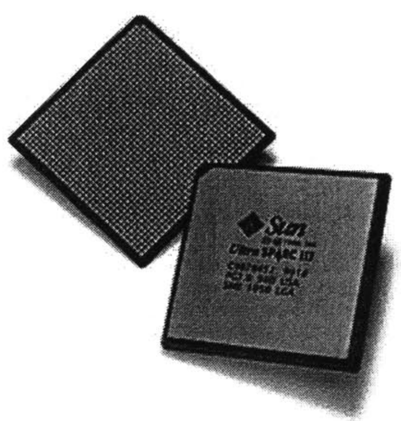

Figure 2-3: UltraSPARC™ III Processor

The SunFire™ V880 is based on the third generation of UltraSPARC™ processors. It can support up to four CPU/Memory boards, each containing two UltraSPARC™ III processors. The UltraSPARC™ III processor is a 4-way superscalar processor with a 14-stage pipeline[25] (shown in Figure 2-4) with six execution units (2 integer, 2 floating point, 1 load/store, 1 addressing).[26]

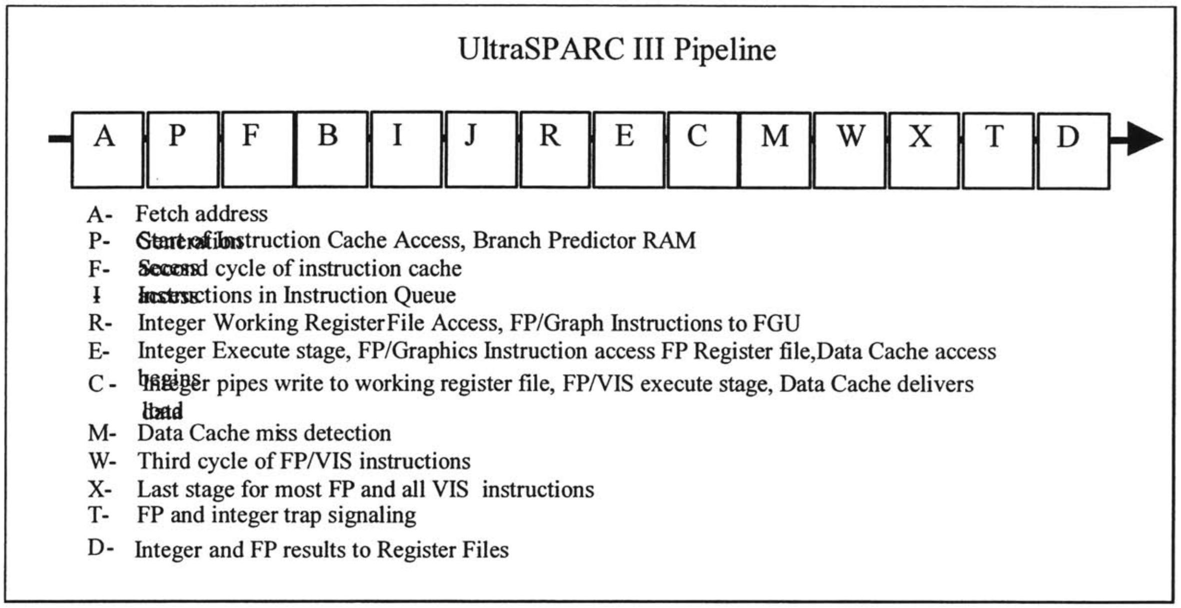

Figure 2-4: UltraSPARC™ pipeline

The processor has 23 million transistors using 0.18 micron, 7-layer CMOS aluminum interconnect technology operating at 1.8 volts. The physical package has 1368 pins. It connects to a 256-bit 150 MHz bus and the core of the processor runs at 750 MHz though increased speeds are planned.

The chip is divided into six functional blocks integrated together to provide complete functionality.

Figure 2-5 shows the blocks and basic flow of instructions through the processor.

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[25] SunFire™ V880 Server System Architecture White Paper, Sun Microsystems Inc., Oct 2001
[26] http://www.sun.com/processors/UltraSPARC-III/index.html

Block Diagram of the UltraSPARC III processor

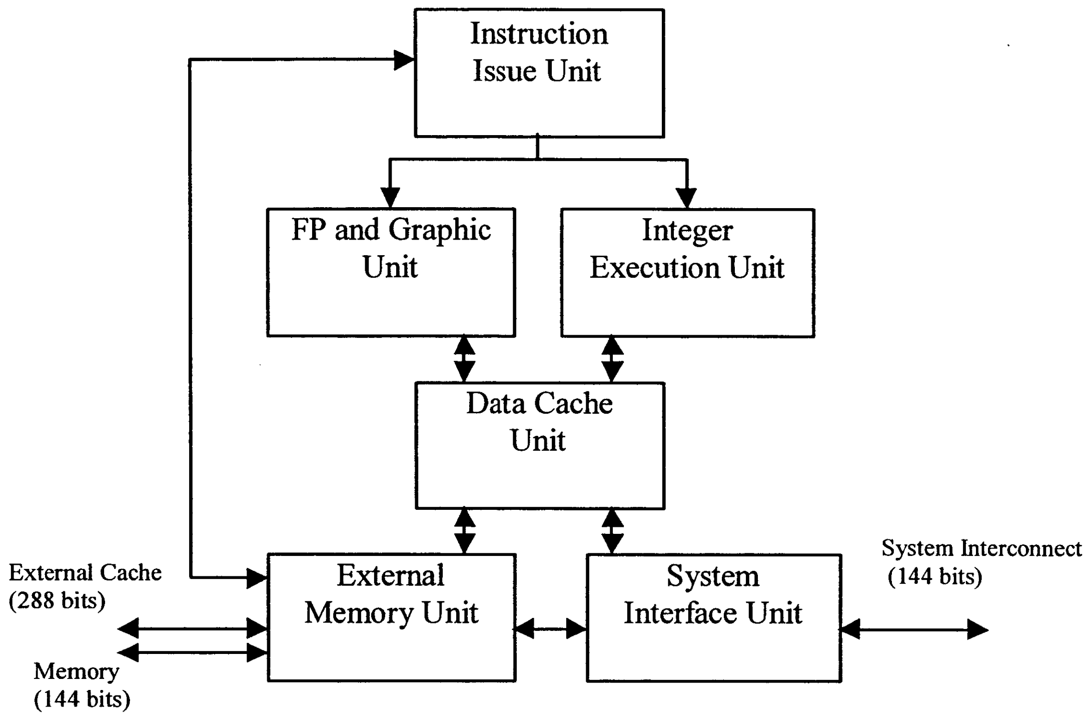


Figure 2-5: Block Diagram of UltraSPARC™ III

Instruction Issue Unit- Fetches instructions and is able to issue 4 instructions per cycle to the execution units

Integer Execution Unit- Executes all integer data-type instructions including loads, stores, arithmetic, logical, shifts, and branches. It is able to handle up to four instructions per cycle

Floating Point Unit- Executes all the floating point and VIS instructions with three data paths for floating point and two paths for VIS instructions

Data Cache Unit- Manages all L1 on-chip cache memories of which there are three: a 64 KB four-way associative data cache, a 2KB, four-way associative prefetch cache, and a 2KB, four-way associative write cache.

External Memory Unit: Controls both the SRAM L2 off-chip data cache and the main memory system.

System Interface Unit: Handles all other off-chip communications including memory, other processors and I/O devices. It had handle 15 pending transaction and out of order delivery.

2.2.2 Fireplane™ Interconnect

The Sun Fireplane™ Interconnect is based on a 6-port crossbar switch. It uses a 288-bit bus (256 bits of data, 32 bits of ECC) running at 150 MHz. It is implemented with four identical crossbar application specific integrated circuits (ASICs). The Fireplane™ interconnect is a mixture of bus and crossbar protocols similar to a NUMA configuration. Data coherency is maintained through a snoop protocol. The two processors on each CPU board are tightly coupled. The boards are connected together via the Fireplane™. To improve bandwidth utilization, each device is able to have 15 outstanding data requests; multiple requests are able to be "in flight" simultaneously.

2.2.3 PCI Buses and I/O slots

The PCI protocol is used to connect peripherals to the main system. There are two PCI bridges that create four PCI buses, two per bridge (see Figure 2-2). One of the buses, PCI bus A, is dedicated to the Gigabit Ethernet and FC-AL connections and has no additional I/O slots. The other three are used to add additional I/O cards and peripherals to the system. There are seven 33 MHz slots, four on PCI bus B and three on PCI bus D. Two 66 MHz PCI slots are available on PCI bus C. The PCI buses are based on PCI industry standards. The I/O slots are all hot-swappable allowing boards to be replaced without disrupting the system. A SCSI connection is included to connect a DVD drive to the system.

2.2.4 FC-AL Connectivity

FC-AL (fibre channel arbitrated loop) is a type of fibre channel enhanced to support copper media and loops of up to 126 devices. The devices are hot-pluggable (they can be added without disrupting the system, but cannot be removed without disruption). The

SunFire V880 supports 1Gb/sec data rates which translates to 100MB/sec throughput. The base configuration can handle six drives. An additional drive backplane can be added to allow an additional six drives. To improve reliability, a redundant network loop can be added to the drive system providing continued data access if one of the network loops fails.

2.2.5 Network Connections

Sun Fire V880 server supports standard network protocols through connectors on the back panel. The supported standards include:

- 10/100 BaseT Ethernet
- Gigabit Ethernet (1000 Base SX)
- USB ports
- Serial ports

2.2.6 Power/Cooling

The Sun Fire V880 is designed to operate with two power supplies. It can be configured with three supplies to allow an N+1 configuration. Both the power supplies and cooling fans are hot swappable. An exploded view of the SunFire™ V880 enclosure is included in Appendix C.

2.3 Commodity Groups

As can be seen from the above analysis, a server is complex product requiring the integration of thousands of parts. The design of the server is broken into subsystems to improve the overall efficiency of the design. Logical boundaries are identified and interfaces are developed to allow concurrent engineering. Likewise the sourcing of a server is broken into groups based on identifiable similarities between parts. The various sub-systems and parts are divided into nine sourcing categories referred to as commodity groups (though none of the groups qualify as a true commodity).

- SPARC Processors
- ASICs
- Boards
- Memory

- Hard Drives
- Power Suppliers
- Enclosures
- Cables and connectors
- Packaging and Peripherals

2.3.1 SPARC

The SPARC processor is considered one of the core components of a Sun server. It is unique to Sun. While it is designed in-house, the manufacturing is outsourced. There are very tight relationships between the external manufacturer and Sun. Sun relies on the use of external process libraries to aid in the design. This reliance and the high switching costs make this a single sourced component. The suppliers are involved in the very early stages of design and work with Sun throughout the development process which typically takes years to complete.

2.3.2 Custom ASICs

There are approximately 24-30 Custom ASICs in a server, though this number varies widely based on the size of the server. There tend to be about 4-5 ASICs per circuit board. The design process for the ASICs is similar to the microprocessor, but ASICs are typically less complicated and may not need the maximum speed obtained from using the leading edge process technology. Suppliers are selected early in the design stage and Sun works with that supplier throughout the process.

2.3.3 Circuit Boards

There are numerous circuit boards used in each server. There is typically a main board (the Fireplane™ in the case of the SunFire™ V880). Other boards plug into the main board to configure a system. The other boards include the CPU/Memory boards and I/O boards. In addition there are supporting boards for power, cooling and system monitoring. The design rules and specification for boards are well understood and portable between manufacturers. Sun does its own board design. There is no need to rely on a single manufacturer for specific design rules. This allows a fair amount of freedom in the sourcing decision.

Boards generally fall into two categories, high-tech and low-tech. This is based primarily on the number of wire layers imbedded within the boards. As the number of layers increases, the number of suppliers able to produce the board diminishes. Sun is often pushing the limits of board technology to improve the bandwidth of the server. In these cases, the need to work with a supplier earlier in the design phase increases. If the boards are low-tech, supplier engagement may be later.

2.3.4 Memory

Servers require a lot of memory. The SunFire™ V880 can be configured with up to 32 Gig of RAM. Sun use standard memory modules to increase their economies of scale and to benefit from sourcing from multiple suppliers. The supply base for memory is concentrated between a few large suppliers. Because memory uses standard interfaces, it is closer to a true commodity. For standard memory products Sun does not need to team up with memory suppliers as early in the product lifecycle. However the supply of memory is fixed in the short term due to the expense and time required to build a silicon fabrication plant (FAB). This creates sizable fluctuations in price as the demand shifts. Sun must balance between getting a low price now and preserving relations to get capacity in a constrained market.

2.3.5 Hard Drives

Hard drives are similar to memory for sourcing consideration. Sun uses standard interfaces for their drives (though in some cases there is minor post-production work done on Sun drives). Because drives follow industry standards, Sun does not need to work with suppliers early in the design stage. Capacity is an issue for drives, however the capital cost to increase capacity is not as great as it is for Memory. As a result, the price swings in drives are not as dramatic as memory. Like memory there are a few big companies that provide the majority of the hard drives to all of the computer manufacturers.

2.3.6 Power Supplies

Power supplies contain a high degree of customization. The need for redundant systems and high reliability promotes the use of custom solutions. There are many power suppliers. Sun chooses to use a subset they pre-qualify on Sun standards. The suppliers are given specifications and perform a large percent of the actual design work. However, because the power requirements are directly tied to the rest of the systems, there is a high degree of change from the original design requirements. These changes require fairly tight relations between the supplier and Sun during the design phase.

2.3.7 Enclosures

Though enclosures don't add a significant value to the server, they are complicated and completely custom. Like the power supplies, the exact specifications of the enclosure are dependent on the rest of the system. This dependency creates a high degree of change in the specifications as the enclosure is designed. There are long lead times for the tooling so waiting is not a good option. There are many enclosure suppliers; however, in recent years the large external manufacturers have been acquiring and integrating companies that specialize in enclosures. As an enclosure is designed, there are many manufacturing trade-offs that need to be made (such as should the holes be punched or drilled). While the end result is the same, different companies have different competencies. This increases the cost of switching manufacturers during production on certain trade-offs have been made.

2.3.8 Cables and Connectors

Some cables and connectors are pure commodities. The power cable and connector are an example. However there are other connectors that are highly customized. The connection between circuit boards is a critical link in servers. Boards have to be easily removable, but connections must be completely reliable. Most of the design work to create reliable connectors and cables is done by the suppliers. Sun is careful with controlling the intellectual property for a given connector so they do not get locked into a single source supplier. The quality of cables and connectors is paramount. Sun only uses approved suppliers to insure quality. Even if cables are custom, the design time is short compared to other components. For standard cables, suppliers can be chosen late in the design phase. For a custom cable, suppliers need to be selected earlier, but not before most of the specifications can be determined.

2.3.9 Packaging

The boxes, padding, and manuals are lower value items that are near pure commodities. They don't represent a significant risk to Sun and there are many suppliers, however Sun never wants to be a situation where a low-value item is gating the delivery of a server. Sun has used this commodity group to reach out to smaller businesses. These businesses provide excellent service even if they are not always the lowest cost providers. Their total costs compared to the system cost are marginal. The global supply team handles the sourcing and purchasing decisions for packaging.

2.4 Design Teams

To integrate the many sub-systems of the server together takes hundreds of man-years to complete and requires considerable coordination between multiple engineering and manufacturing groups. To coordinate the design process, the design of a server is broken down into concurrent tasks, each handled by a different design team. There is a central Board/System team that acts as the general contractor for a new system. They are responsible for the overall design and connectivity for all of the integrated parts that make up a server. They interface with all of the other teams involved in the project. The central team provides support and makes many of the design trade-offs between features and functionality. The various components of the server (boards, ASICs, power supplies, and enclosures) are designed by teams that are either a part of the central product team or reside elsewhere in the organization.

Each component of the server must integrate seamlessly into the system. Since the system parts are designed in parallel, there are complex interdependencies that must be carefully monitored and controlled. As an example, the power specifications are dependent upon the board and ASIC designs, but waiting until the circuit board and ASIC designs are complete to start the power design is impractical and inefficient. Therefore a specification for both is developed and adhered to. This allows concurrent design efforts. These same types of trade-offs and dependencies exist between many of the different systems and components used in the server. As the various sub-systems are completed, they are combined, tested and debugged. The end result is a fully functional server ready for commercial application.

3 IMPLEMENTING DYNAMIC BIDDING AT SUN

3.1 Moving to Reverse Auctions

Each of the commodity groups within Sun has developed long-standing relations with their supplier base. To source a product to Sun, a company must go through a stringent evaluation process and is then placed on an approved supplier list (ASL). There are typically between 3 and 15 suppliers in a commodity group on the list. Because the list of approved vendors is relatively small, relations tend to last for many years and span multiple projects. Engineering and procurement grow accustomed to working with the same group of suppliers. Each commodity group has a set of informal norms for working with their supply base. These norms evolved over time and represent the individual challenges of each commodity market.

Into this setting, Sun introduced reverse auctions in May of 2000. This was not a random or sporadic decision, but a carefully considered strategic shift meant to address a number of issues facing Sun as it entered the twenty-first century. The server market had become increasingly competitive. Low cost players such as Dell were entering the market; the profit margins on servers were decreasing. Coupling this shift with the recent economic downturn, the need to trim costs and improve efficiency became paramount. Sun's entire supply chain needed to react to these changes to stay competitive.

Scott McNealy is a strong proponent of e-business and in particular of on-line auctions. He pushed Sun to use reverse auctions as a way to drive costs down and drive discipline into the sourcing process. It was a considerable shift from the existing sourcing method for both suppliers and for Sun's internal sourcing teams. It was met with enthusiasm and skepticism.

3.2 Implementing Reverse Auctions

Sun considered the benefits and costs of using reverse auctions before experimenting. They concluded that the primary benefits were:

- Reverse auctions create truly competitive markets and establish the real market price for a good or service.
- They streamline the sourcing process and reduce the cycle time for making a sourcing decision.
- They objectify the sourcing process, creating a more level playing field to compare suppliers.
- They provide suppliers with real market data and instant feedback on their competitiveness.

The costs associated with dynamic bidding were more difficult to quantify; management was concerned about how suppliers would react and what it would do supplier relations. They concluded that it was worth piloting, but that they needed to monitor the process carefully. They chose FreeMarkets Inc. as their auction provider and tweaked the default auction process to fit Sun's specific needs. While a pure reverse auction would always award to the lowest bidder, Sun reserved the right to not award the lowest bidder. They recognized they were not auctioning pure commodities and that it was not practical or wise to evaluate suppliers based on price alone. To distinguish the Sun version from a standard reverse auction, the term *dynamic bidding* was applied to the Sun model.

To drive internal adoption, Sun created an internal team of market makers to complement the marketmakers supplied by Freemarkets. This internal team of 3-4 people was tasked with:

- finding opportunities to use dynamic bidding
- insuring all events meet Sun's high standards
- creating a set of rules and best practices to improve the process
- driving internal adoption throughout Sun

As a central repository of information and experiences, they provided a consistent, reliable point of reference for managers and sourcing specialists within Sun. This allowed the initiative to rapidly progress as the team learned from past mistakes and tweaked the process to compensate.

3.2.1 The Dynamic Bidding Process

While the online dynamic bidding event takes only a few hours to conduct, there is considerable preparation and post work that must be done to insure the overall process is a success. To verify that each event was properly set-up and executed, the internal market making team created a flow diagram that outlined the steps involved to perform a successful auction. There are eight steps in the flow as shown in Figure 3-1.

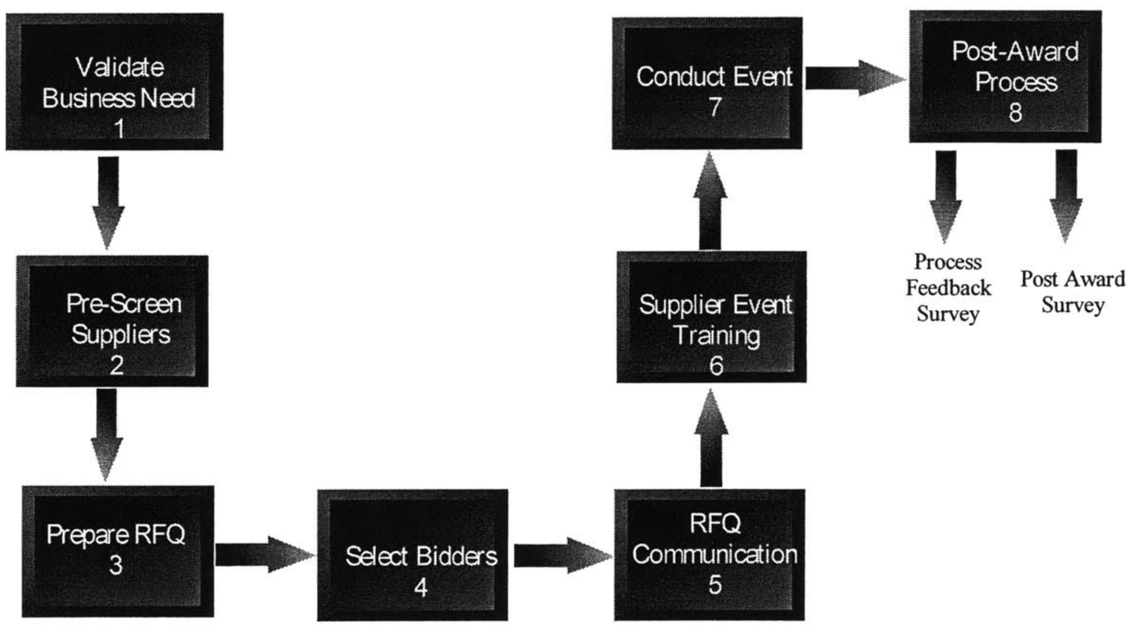


Figure 3-1: Process flow for Dynamic Bidding

The eight steps can be broken into three groups: pre-event efforts, the bidding event, and post event efforts.

3.2.1.1 Pre-event preparation

The majority of the reverse auction work takes place in the pre-event preparation. There are six steps included in the pre-event preparation. The steps are self-explanatory yet important to the overall success of the auction. If the preparation is not done properly, the results of the auction are much less likely to be favorable. For example, in a particular cable event the award winner was found to be unable to produce one of the cables they had won production rights for. This supplier should have been pre-screened prior to the event. The delayed result was a non-optimal award decision.

The most critical element of the pre-work is preparing the Request for Quotation (RFQ). The RFQ contains a detailed specification of the product and all the other operational parameters that suppliers are expected to meet. It may include standard terms and conditions, quality requirements, delivery requirements, and/or hubbing expectations along with any other specific requirements expected of the supplier. In traditional negotiations any confusion or issues with the RFQ could be resolved throughout the process. In a dynamic bidding event, they must be resolved before the event. It is also vital that each supplier understand precisely what the specification means. If suppliers make assumptions as to the meaning of a parameter, their bidding and thus the event results could be affected. In an enclosure event, the turning of the edges of the enclosure (a common procedure to remove burrs from the metal) was not explicitly specified in the specifications. The award winner did not include this cost in its quotation. When this inconsistency was discovered, the supplier raised their price to cover the additional cost of turning the edges. It is very likely that one or more of the other suppliers invited to the event included this cost in their original bid. This mismatch could have caused the award decision to be misplaced.

3.2.1.2 Event Day Activities

The actual on-line events are generally very short, typically a few hours in length. Invited suppliers log onto the event over a secure Internet connection. The amount of information they are allowed to see depends on the event. In a typical situation, the suppliers would only see their bids and rank in the event. In a limited number of situations, supplier may be allowed to see competitor's bids. The buyer, on the other hand, sees all the suppliers simultaneously and can track who is doing what. Figure 3-2 is a screen shot the buyers view of a bidding event.

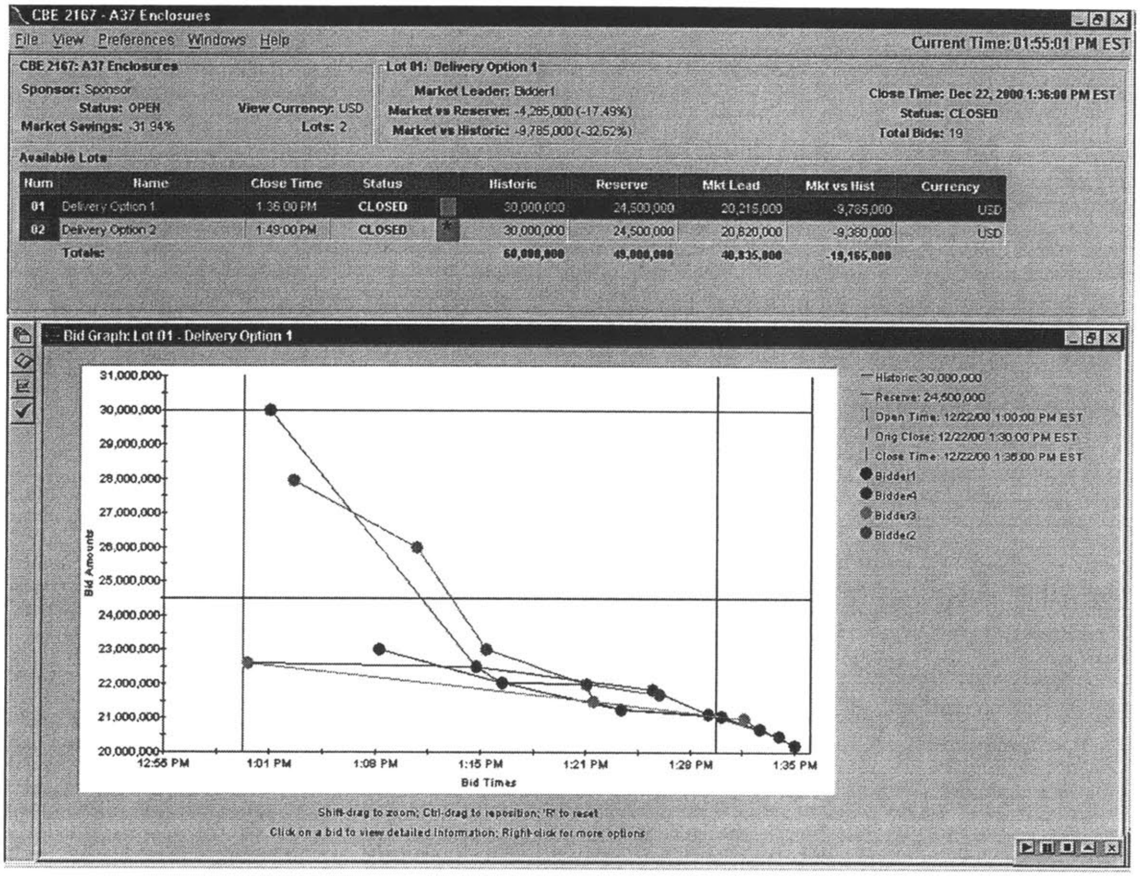


Figure 3-2: Screen Shot of Bidding Event

A single bidding event might have three to four smaller auctions within it. These smaller events imbedded within the larger auction are referred to as lots (similar to conventional auctions). Figure 3-2 is a screen shot of the results of a lot event. The bidding on lots occurs sequentially. Bidding on lot 2 would begin immediately after bidding on lot 1 ended. Often the same suppliers are bidding on sequential lots.

Suppliers bid on the total price. It is up to each supplier to understand the detailed breakdown of their cost and to know their minimum price before the event begins. There are two prices set by the Buyer and given to the suppliers prior to the event:

- The **ceiling price** is the highest allowable bid, no bids are allowed above this price.
- The **reserve price** marks the point that Sun will commit to a supplier. If at least one supplier bids below the reserve price, Sun guarantees that it will make an award decision (though not necessarily to the supplier who bid below the reserve price) If no supplier bids below the reserve, Sun is not obligated to make an award decision.

If there is bidding activity within 1 minutes of a lot closing, the lot auction will be extended until there is no additional activity for one minute or a hard stop limit is reached (Sun decides which option they will use on a case by case basis). There is typically light activity during the early stages of the auction that increases as the end approaches. The actual bidding environment can be quite exciting given the dynamic nature of bidding.

3.2.1.3 Post Event Activities

After the event, supplier must provide a detailed breakdown of their costs to justify their bidding. This helps insure they can deliver on the set price. It also creates a price benchmark that can be used to monitor price creep over time. The suppliers are also required to provide a detailed plan for the quality, delivery, capacity and other non-price parameters to insure they can meet Sun's requirements prior to the award decision. This post event work helps to insure the best supplier is awarded the business not necessarily the lowest cost supplier. Award decisions are made within a week or two of an event closing.

3.2.2 Cardinal Rules of Dynamic Bidding

To insure that the basic goals and objectives of dynamic bidding are met with each event and to provide consistency across Sun, the process flow was augmented with a set of absolute rules regarding dynamic bidding events. These rules are referred to as the cardinal rules. The rules provide a basic guideline to determine if a sourcing decision is suitable for a bidding event. The rules are:

1. Commitment to integrity of the Market Making process
2. There has to be a real sourcing decision to be made
3. Must be able to create a market
4. Create markets consistent with:
    - commodity and EM strategies
    - established Sun sourcing policies and practices

3.2.3 Dynamic Bidding Goals for the first year

Sun set an aggressive target to source $1 billion USD through dynamic bidding events in the first year. Each business division and commodity group was tasked to find opportunities to use the dynamic bidding process. The internal market making team drove adoption and worked with managers to identify opportunities.

3.3 Dynamic Bidding at Sun FY01 Results

The first Dynamic Bidding Event was held on May 3, 2000 with 5 lots of printed circuit boards valued at over $10 million USD. The average savings from that event was 40% over the historic cost of the boards. Since that time Sun has run over 40 events totaling over 90 lots and a dollar volume of $1.1 billion USD. The aggregated averages for Sun's events to date are presented below in Table 3-1. Note that these numbers are by lot average and are not dollar average (savings of 40% on a $1 million USD lot weighs equally as a 20% savings on a $100 million USD lot). The high standard deviation warrants caution when interpreting these results or forming assumptions about what a typical event should be. The annualized dollar-average savings for fiscal year 2001 is approximately 20%. From Table 3-1, it can be seen that the average savings per lot is

30%. This means the average savings on large dollar value lots is lower than the average savings on smaller dollar value lots.

Table 3-1: Average Savings from Bidding Events in 2001

	AVERAGE	STD DEV
Avg $/Lot	$12,875,348.15	$21,305,909
Expected Savings/Lot	21.51%	20.81%
Avg Identified Savings/Lot	33.27%	19.72%
Avg Implemented Savings/Lot	30.25%	20.62%
Avg Lost Savings/Lot	3.02%	8.73%
Avg # of participants	4.4	2.44
Avg # of bids	28.33	24.37

3.3.1 Commodity Statistics

Below is a table containing data from events conducted in six of Sun's nine commodity groups. The results within each commodity group vary significantly as do results across the commodities. Figure 3-3 shows the averages for each commodity group.

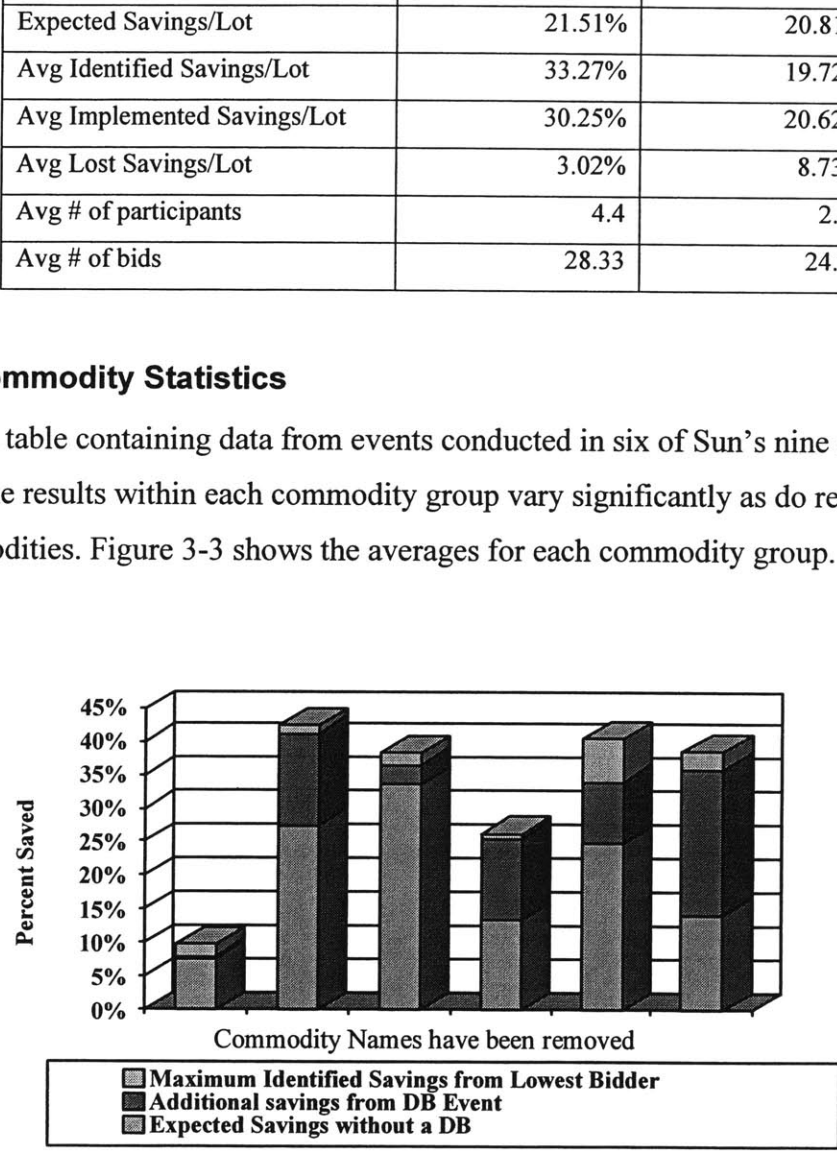


Figure 3-3: Average Savings per Commodity Group (not annualized)

Each bar in Figure 3-3 has three sections. The first section (bottom) is what Sun expected to save using their historic method of negotiation prices. The second bar (middle) shows the additional savings Sun realized through dynamic bidding. The third section (top) shows the maximum savings identified through the dynamic bidding event, but was not captured due to other constraints (This could occur from choosing the second lowest bidder, or splitting the award between two suppliers).

Figure 3-3 shows that savings across the different commodity groups varies significantly; the variation within each commodity group also varies significantly. Figure 3-4shows a scatterplot of lot savings organized by commodity groups.

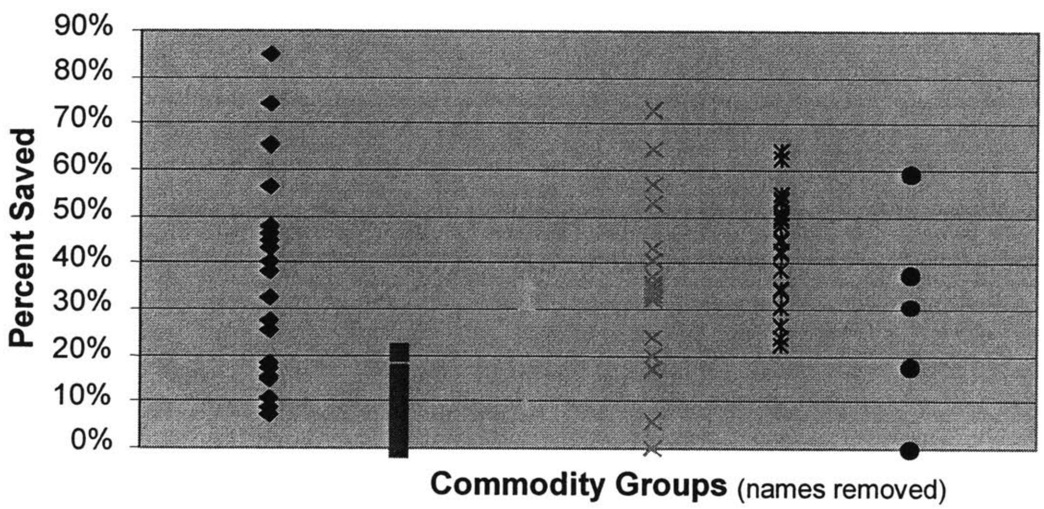


Figure 3-4: Scatter plot of Percent Savings by Commodity Group

The high variation within each commodity group implies that there are other factors beyond the commodity group that affect the outcome of a bidding event. The following parameters were studied to identify a correlation with lot savings:

- The total dollar value of the lot
- The number of bidders participating in the lot
- The length of contract for the lot
- The event date

3.3.1.1 Savings to Dollar volume

Figure 3-5 shows a plot of savings to dollar volume of the lot. The X-axis of the chart is a log scale. There appears to be a peak savings around $1-10 million USD; there is not enough data to statistically prove this is the peak savings for all commodity groups. It is very unlikely that all the commodity groups would have the same optimal dollar volume. However it is likely that there is an optimal range for the dollar volume for each commodity group. On the one side, if the dollar volume is too low, suppliers will not be motivated to bid competitively. On the other side, as the dollar volume increases, it is easier to focus on changes in dollars instead of percents. Suppliers generally bid on the total price, not the unit price. A $100,000 drop on 10 million dollar volume is a significantly greater percentage than the same drop in a 100 million dollar volume. However, in either case, dropping the price by $100,000 seems significant. Between these two effects, there would be a sweet spot for dollar volume. At present, that this appears to be around five million dollars. This will likely change as more data is gathered.

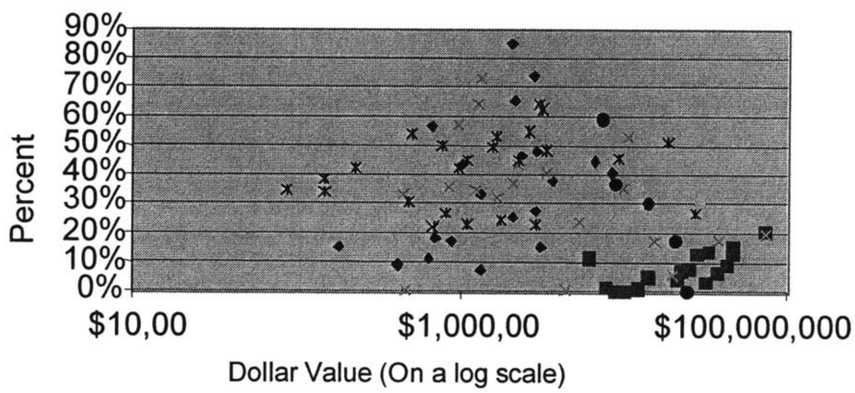


Figure 3-5: Savings to Dollar Volume (Log Scale)

3.3.1.2 Savings to Bidders

Figure 3-6 shows a scatter plot of percent savings by lot to the number of bidders. The maximum and minimum savings from three to five bidders is similar. The averages for 2-5 bidders are shown in Table 3-2. (There is not enough data above 5 bidders to draw conclusions yet.) The average savings increases as the number of bidders increases, however the number of bidders is not distributed evenly across the commodity groups and the number of data point in the subsets varies. The standard deviation is high. There is not enough data to form conclusive results about the correlation between the number of bidders and savings, though it appears that more bidders do increase savings.

Table 3-2: Average Saving by Number of Bidders

Number of Bidders	Average Savings	Std Dev
2	26%	15%
3	28%	22%
4	35%	16%
5	38%	23%

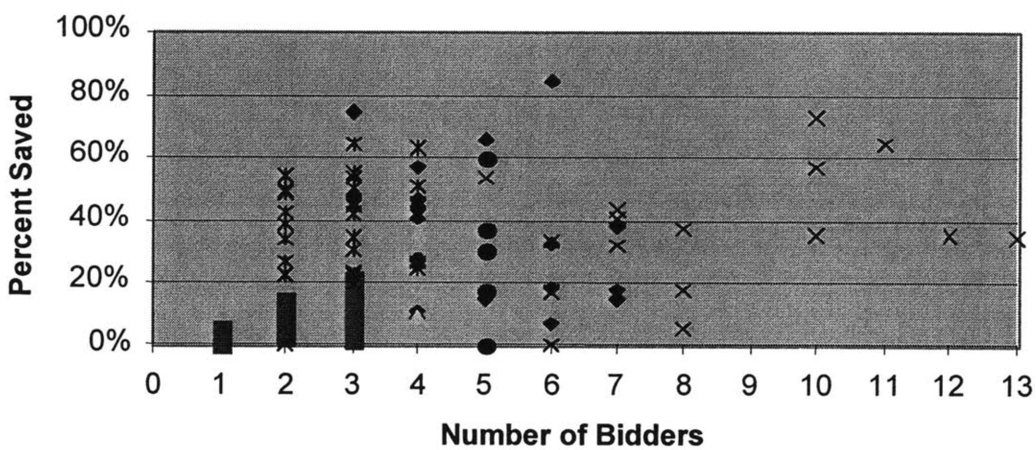


Figure 3-6: Percent Savings to Number of Bidders

3.3.1.3 Savings per Contract Length

Figure 3-7 shows the savings to contract length. The x-axis measures the contract length in quarters. The difference in average savings between a 4-quarter contract and a 6-quarter contract is 6%. (33% and 39% respectively) One would expect the savings for a 6-quarter contract to be higher than for a 4-quarter contract since the price is fixed at a given level longer. This appears to be the case. However commodity groups have standard contract lengths; between 80%-100% of the data points within a commodity group fall within a single contract length. Thus the difference between the 4 quarter and 6 quarter savings could be influenced more by the commodity groups than the length of the contract.

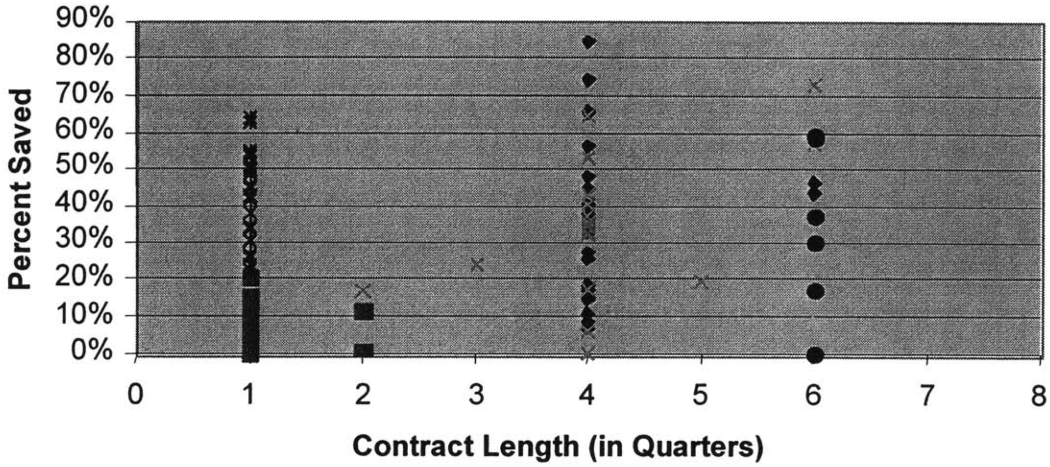


Figure 3-7: Percent Savings to Contract Length

3.3.1.4 Savings to Event Date

While there was no expectation to identify a trend in savings to event date, it was a simple task to verify this expectation. Trends in savings over time might indicate learning patterns in the supply base or reflect general market conditions. As shown in Figure 3-8, no patterns were found.

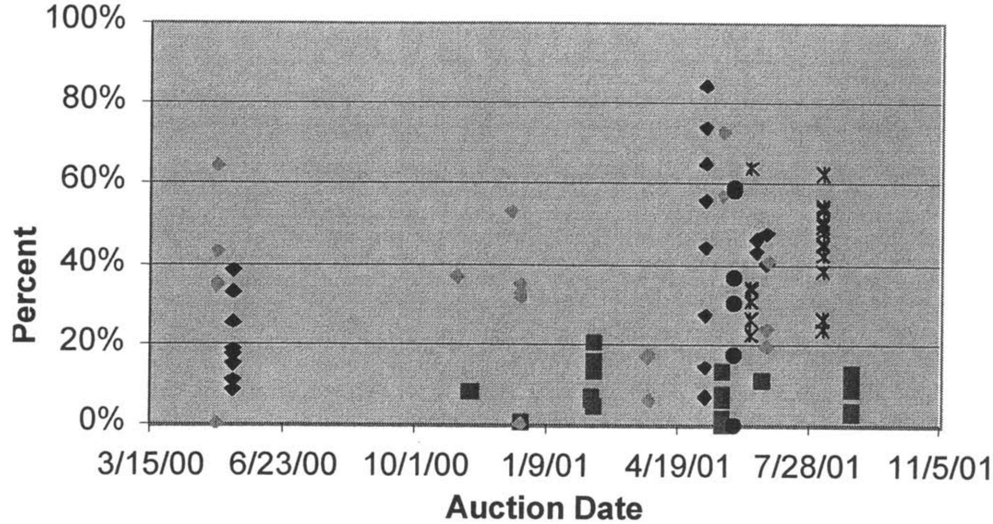


Figure 3-8: Percent Savings to Auction Date

3.3.2 **Incumbent vs. Lowest Bidder Awards**

Another important trend is the percent that the incumbent wins and the percent that the lowest bidder wins. These percentages send signals to the suppliers about where Sun's value lie. Always awarding to the lowest bidder will signal that Sun places a high value on cost savings. Always awarding to the incumbent will signal that Sun is using the bidding process as a benchmark for pricing and not a real sourcing decision. Figure 3-9 shows the percent for the commodities groups based on events to date.

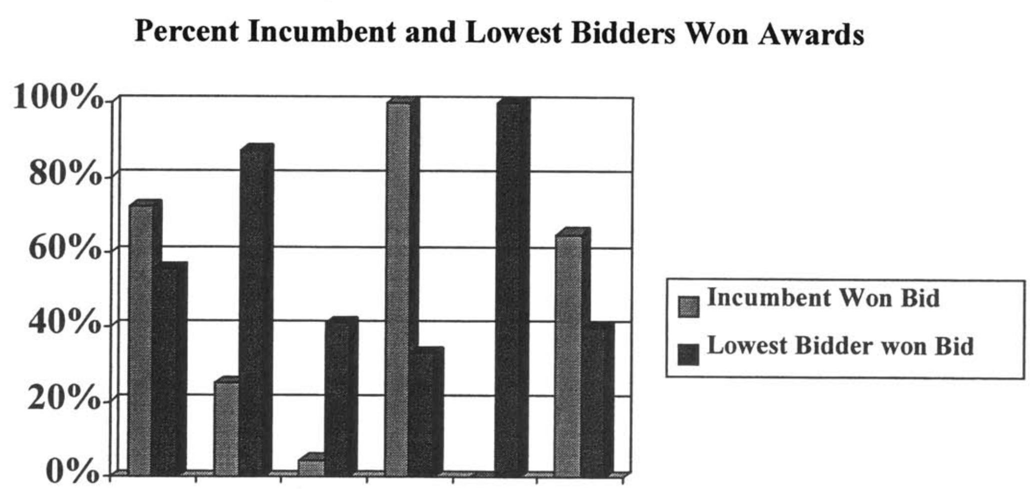


Figure 3-9: Incumbent vs. Lowest Bidder Awards

3.4 Overall Conclusions from Scatter plots

The overall results from the analysis of the scatter plots are still inconclusive regarding optimal bidding parameters. The initial trends indicate that

- One to ten million dollars is a good target volume for the auction
- The more bidders the better
- No valid conclusions can be drawn from contracts lengths
- There is no relation between event date and savings

The trends indicate that Sun has tuned their guidelines to provide positive results and that there are not any fundamentally flaws in their process. They should continue to organize and run bidding events using their existing rule set. Sun should continue to monitor these statistics and be ready to change if adverse trends begin to appear.

4 DYNAMIC BIDDING IMPACT ON SUPPLIER RELATIONS

The analysis in the previous chapter is concerned only with the dollar savings achieved through a bidding event. An equally significant factor is the impact to supplier relations from bidding events. This chapter will first look at how to define supplier relations and then look at feedback and behavior from both Sun suppliers and Sun sourcing owners to gauge the impact on supplier relations from prior dynamic bidding events. This does not necessarily correlate to the long-term impact to supplier relations, but it serves a guide for where they might be headed.

4.1 Definition of Supplier Relations

The definition of good supplier relations may seem obvious: provide the product to the buyer before the due date with perfect quality, proactively looking for areas to improve. If a supplier agreed to provide the above conditions, most buyers would consider that good supplier relations, however if the supplier also increased the price by five hundred percent, the supplier relations might not seem so favorable. The question of good supplier relations is about value.

The first question for determining what are good supplier relations is to know what is the desired relation. The burden for this falls on the buyer. A buyer who doesn't understand what they need cannot blame a supplier for not providing it. An informal Sun Survey was conducted among internal sourcing experts. It found a great mix of what good supplier relations means. The results included the following:

- Collaboration/Partnership
- Trust
- Communication
- Turn on a dime
- Responsiveness
- Balanced expectations
- Help in a crunch
- Provide competitive pricing
- Meet Sun's needs

These traits can be summarized into ***supplier's willingness***. A willing supplier will turn on a dime, help in a crunch, and meet Sun's needs. What was not mentioned was the value of each of these parameters. In an ideal world, they would all be free. However this is not practical or realistic. When the cost of willingness is taken into account, the definition of good supplier relations must include the right amount of supplier willingness and getting it for the lowest total cost. It takes time, trust, and money to build a relationship. It cannot be bought at a moments notice for instant results.

Good Supplier Relations are:

The right amount of supplier willingness obtained for the lowest total cost

For a pure commodity, the needed supplier willingness could be very low, and thus good supplier relations could be no relation. There is little value having a nut and bolt manufacturer willing to make custom changes since such changes are rarely needed. For a complex part or a scarce part, the need for supplier willingness could be high. In this case, good supplier relations may include offering design help, reserving excess capacity, and making quick changes all at a minimum price. Though the relations in the two situations are very different, they are both examples of good supplier relations since they have the right amount of supplier willingness obtained at the lowest cost.

There are two basic ways to create and maintain supplier willingness: mutually beneficial willingness and forced willingness. Mutually beneficial willingness is when a supplier is able to choose the best option from a set of good options. Forced willingness is when a supplier is forced to choose the least bad option from a set of unfavorable options. There is a continuum between the two types of willingness. The appropriate balance depends on the market power of the buyer/seller and the relation requirements. Many firms seek to find collaboration where a supplier and a buyer both realize their best benefits from the relationship. On the other hand, monopolies generally use forced willingness opportunistically to gain the lowest cost relations for themselves.

4.2 Effects to Sun's Supplier Relations

The precise long-term effects to Sun's supplier relations due to dynamic bidding are not known. This analysis is beyond the scope of this thesis. However, the current feedback from suppliers and Sun sourcing experts does reveal some useful insight into where relations may be headed.

Information was gathered from six of Sun's suppliers and twenty-one of Sun internal sourcing experts through informal interviews (more on these interviews is included in the next chapter). The data reveals that supplier sentiment regarding dynamic bidding is polarized. Suppliers winning new bids typically see advantage to the process and are optimistic about bidding. Most of the remaining feedback is negative. This is not surprising. The negative feedback falls into two categories, implementation feedback and model-use feedback.

The implementation feedback from suppliers specified event characteristics that made the process difficult or annoying. This feedback was analyzed and used to modify the process to make bidding more attractive to suppliers. Some of the early feedback from suppliers indicated that the training was inadequate and that there were no simulations. The process was changed to fix these problems. This type of feedback shows suppliers are interested in the process and want to preserve relations. Sun's reaction signals to suppliers that Sun is willing to take an active roll in preserving relations. It is unlikely that this sort of feedback holds negative long-term effects on supplier relations.

The model-use feedback from suppliers indicates that most suppliers feel dynamic bidding gives a one–sided advantage to Sun. The more common complaints were:

- Suppliers feel threatened by the process
- Don't believe it fosters a mutually beneficial relationship
- Trust has been violated
- One company threatened potential retaliation during a capacity constrained market.

This feedback reflects a change to supplier relations at Sun and suppliers' discomfort with a new process. Bidding appears to be moving Sun suppliers closer to forced willingness from beneficial willingness. While this shift does not mean relations are destroyed, it does mean how they are handled and the amount of supplier willingness will likely change. Whether supplier willingness has dropped below a minimum level or not is commodity and product specific. It will also be highly dependent on each event and supplier expectations regarding the event.

Despite the negative feedback, suppliers have maintained an acceptable level of willingness as they participate in bidding. One of the commodity groups now relies solely on bidding for award decisions. This commodity group has a low level of customization. Initially there was strong negative feedback from the suppliers. However, the most vocal supplier later provided additional capacity at the dynamic bidding price point when an alternative supplier failed to maintain acceptable quality standards. This situation occurred more than once and each time the supplier was willing to provide the extra capacity at bidding prices. This same supplier has subsequently informed Sun they approve of the process and want Sun to continue to use the process. They have realized efficiency gains from bidding (as well as market share). The internal commodity team worked hard with these suppliers and implemented numerous changes in the process based on supplier feedback. Their efforts have captured additional savings while maintaining enough supplier good will to support Sun's needs. It appears that the feedback was due to discomfort with the process as opposed to a lasting degradation of supplier relations.

In general, commodity groups dealing with a custom product gave more push back than less custom commodity groups. Suppliers that had a high degree of design collaboration with Sun disliked the focus on pricing. A portion of the feedback was linked to unmet expectations. Suppliers felt Sun was leveraging market conditions and some disliked how Sun implemented the tool. These issues are looked at in the next chapter.

5 FACTORS AFFECTING AUCTION RESULTS

Chapter 3 looked at the trends in bidding parameters and how they relate to cost savings. Chapter 4 looked at the supplier relations and how they have changed due to dynamic bidding. In both cases there appear to be many other parameters that are significant in determining the results of dynamic bidding. This is a predictable conclusion. It would seem quite unrealistic to get similar savings in a capacity constrained market compared to an excess capacity market solely because a similar auction format was used. Likewise suppliers who have been involved in sole-sourced relations in the past will have a different outlook on bidding than suppliers who are routinely subject to intense price competition.

This chapter looks at the impact to supplier relations based on less quantifiable but significant factors, such as market conditions. Antidotal evidence gathered from internal and external interviews and research was used to identify and organize the key factors. The trends fall into two categories, internal factors and external factors. Each will be looked at in this chapter. It is beyond the scope of this thesis to provide statistical evidence for the exact relevance or impact of these factors.

5.1 Results from Interviews

Twenty-one internal Sun commodity managers and sourcing experts were interviewed and asked a list of questions regarding their experiences with dynamic bidding. They were asked about their historic method of sourcing, how they obtained negotiation leverage prior to dynamic bidding, what results they had seen from bidding, and their overall impression of dynamic bidding. The complete list of questions is included in Appendix D. The sample set of individuals who were interviewed included at least one individual from each commodity group and included varying levels of experience with dynamic bidding events. This information was combined with direct feedback from six suppliers and interviews with six other companies who are using or considering using reverse auctions. The results from all of the interviews were compiled and common trends were identified. The significant factors fall into two classifications:

- The external risk factors including current market conditions, capacity constraints, technology requirements and quality risk.
- The internal business environment (between Sun and suppliers) including typical business practices and expectations.

5.2 External Risk Factors

The external risk factors are general (non Sun specific) market conditions within a commodity group and the risks associated with the technology and quality of the commodity. The external risk can be categorized into four types of risk:

- Market Risk: Consolidation and market power risk
- Supply Risk: Capacity constraint risk
- Design Risk: Technology and design cycle time risks
- Quality Risk: Risk of failure

5.2.1 Market Risk

The concentration of suppliers and the overall size of a market play a key role in determining channel power. If the supply base is fractured and/or the buyer's purchases are a significant portion of the total market, the buyer has considerable market power and can use this leverage to obtain the best in class pricing. It is not surprising that the six companies interviewed who were using or considering using auctions were industry leaders and had considerable power over their supply base.

There is a risk of consolidation. Opportunistic behavior from powerful buyers can drive suppliers to consolidate and eventually to gain pricing power. The automotive industry has seen this effect in their relations with part suppliers.[27]

[27] James P. Womack, Daniel T. Jones, Daniel Roos, The Machine that Changed the World: The story of Lean Production, HarperCollins, 1991

5.2.2 Supply Risk

Supply risk is similar to market risk. Market risk focuses on the companies; supply risk focuses on capacity. Capacity is a critical factor in the supply and demand balance. Capacity is controlled by two main factors, the cost of adding more capacity and the time required to add capacity. Commodities like standard memory that rely on silicon fabrication plants (FABs) have a fixed capacity in the short term since cost and time to add capacity are both high. This can cause the price for silicon products to swing significantly to compensate for fluctuations in demand. Where additional capacity is cheap and easy to bring online, prices tends to be more stable. These effects will be significant in determining the outcome of a dynamic bidding event.

5.2.3 Design Risk

Design risk includes the technology and the cycle time to design a part. These factors help determine the qualified supply base and intellectual property issues. If the needed technology is cutting edge, the capable supply base will be smaller and the amount of buyer leverage diminishes. The design cycle time is relevant if a supplier is co-designing. A two-year design cycle will incur more development costs than a two-month project. Suppliers involved in a two-year design project will require a greater commitment from the buyer for future production rights. The level of integration between the supplier and buyer will be higher which will increase switching costs.

5.2.4 Quality Risk

Quality risk measures the exposure for part failure. Exposure is composed of two parts, the direct financial exposure for replacement and the longer-term risk of tarnishing a brand image. Both aspects should be considered when selecting a supplier. The value from saving a few cents on a part could be shadowed by the larger cost of replacement. The focus on a bidding event is the production cost. This focus on the immediate ROI could cloud judgment regarding the true costs including the quality risk cost.

5.3 Internal Business Environment:

The internal business environment refers to the expectations and typical business practices between the suppliers within a commodity group and Sun. It might be informally described as: *What is business as usual?* The amount that business as usual deviates from a bidding event correlates to the amount of pushback from suppliers and the ease of conducting a successful event. Three specific areas of the internal business environment appear to be linked to the success of a bidding event are:

- The level of stability of the specifications used in the RFQ
- What is included and expected in non recurring engineering (NRE) expenses
- The level of commitment and engagement suppliers assume verse what is explicitly communicated via contracts

5.3.1 Status of Specifications

The status of the specifications for the good or service being auctioned is important for two reasons. First, specifications create a level playing field for the suppliers. Second, post-bidding-event changes to specifications create loopholes that suppliers can leverage to increase their margin.

Successful bidding events require that a level playing field is created where all suppliers have equivalent information and therefore can compete on an equal level. In order to fulfill this requirement, it is vital that the state of the specifications given to suppliers does not allow room for assumptions. Suppliers can make different assumptions. These differences can cause inconsistent bidding and mask the best supplier for the product.

Bob Emiliani, professor at Rennselaer Polytechnic Institute states: "I know a company that makes a product for a customer who typically submits incomplete blueprints. The supplier knew how to overcome this, but lost the business when the parts were put up for bidding. However, a few months later, the orders began to trickle back in because the other bidders couldn't make them."[28] Incomplete specifications reduce the value of bidding events.

A bidding event is a legally binding contract. If Sun changes the nature of the good or service after the bidding event, the contract is compromised and the supplier has the opportunity to re-price the good or service to reflect the changes. This creates a loophole where suppliers can increase the price. While this is not unique to dynamic bidding, the cost focus of a bidding event makes the likelihood of suppliers inflating the true cost of changes much greater. This behavior was suspected in at least one event, however no empirical data was available to substantiate the claim. To mitigate this risk, minimal changes to specification should be made after a bidding event.

Data gathered from sourcing experts and engineers indicate that Sun initiates many change order requests (CUBs) after suppliers are selected. Data also indicates that there are have been significant increases in product costs during the development phase. These changes are not related to the dynamic bidding, but should be monitored to minimize the impact to Sun's sourcing decision.

5.3.2 Non-Recurring Engineering (NRE) Expenses

Dynamic Bidding is successful only if both Sun and its suppliers understand the total cost, including the less tangible costs like NRE. Many suppliers waive part or all of their NRE costs with the assumption that they can roll these expenses into the production costs later on. This assumption creates an uneven situation for suppliers bidding on a new product.

NRE is defined differently for different commodities within Sun. In the traditional sourcing process, NRE was a channel for suppliers to provide extra value and thus obtain an advantage in the sourcing process. DB's reverse this advantage for suppliers. High service level suppliers must compete with other suppliers who may not offer the same service level. The lower service is typically less expensive, thus provides an advantage in

[28] Jim Ericson, "Reverse Auctions: Bad Idea?" Line56, Sept 20, 2001

a bidding event. To reduce the confusion associated with NRE, Sun should develop a consistent definition for NRE and publish guidelines for paying NRE expenses.

5.3.3 Contracts during the Design Development Phase

Over 90% of the polled sourcing experts indicated that their relationship with a supplier was for the life of the product. This indicates that re-bidding through dynamic bidding is a shift in "business as usual". Although Sun explicitly states that suppliers are not guaranteed production volume, suppliers typically assumed that they would receive future production volumes. This assumption was generally correct. However, when their expectations were not met, due to either a dynamic bidding event or other reasons, there was a sense that their trust had been violated. This is not a flaw of the dynamic bidding process, but rather a communication problem.

5.4 Areas for Further Research into Factors Affecting Bidding

There are many reasons a bidding event may or may not be successful. This chapter has indicated only a few that emerged from the interviews. The conclusions of this chapter are based on antidotal evidence and are thus subject to variation and error. They represent the best data available at the time, however a great deal more research could be done to evaluate the significance of the internal and external factors affecting dynamic bidding. The key point of this chapter is that there are internal and external factors that are linked to bidding results and not exactly what the relation is.

6 SUPPLY CHAIN LEVERAGE STRUCTURES

The previous chapter looked at internal procedures that affect supplier relations. This chapter addresses how to structure the internal procedures to align with design and production goals. The purpose of a sourcing tool is to improve a company's overall cost savings. The goals of the sourcing decision should drive the choice of which sourcing tool to use. The sourcing tool itself should not drive the nature of a sourcing decision. While the reverse auction is a useful tool, it is not right for all sourcing situations.

This chapter will look at different sourcing structures (called leverage structures) and present a framework to select leverage structures based on the goals of the sourcing decision. The leverage structures are not limited to reverse auctions. The flowchart in

Figure 6-1 represents a decision framework that can be used to select a leverage structure. Once the preferred leverage structure is selected, the internal processes can be aligned to support that structure. This framework will be described in detail in this chapter.

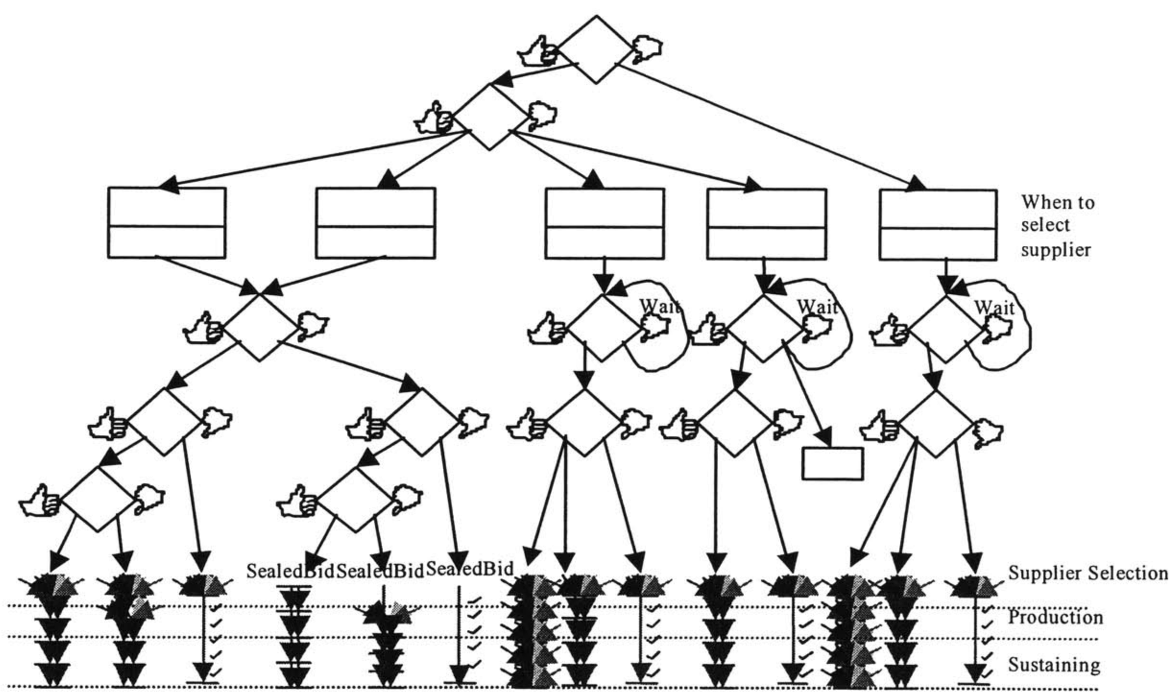


Figure 6-1: Selecting a Supply Chain Leverage Structure

6.1 Background on the Sourcing Decision Process

If all sourcing decisions could be made after a design was complete with an infinite choice of suppliers of exactly equivalent quality and delivery there would be very little need for different supply chain leverage models. However this is not the case. At Sun, a large percent of the design work is done in collaboration with suppliers. The nature of each relationship and the needs of each product vary. This variation creates a complex sourcing situation. At times, supplier must be engaged early during engineering. This relation then transitions to production as the design is completed. These dual relations makes designing a leverage structure challenging but vital. The two phases of supplier relations as related to the product life cycle are shown in Figure 6-2.

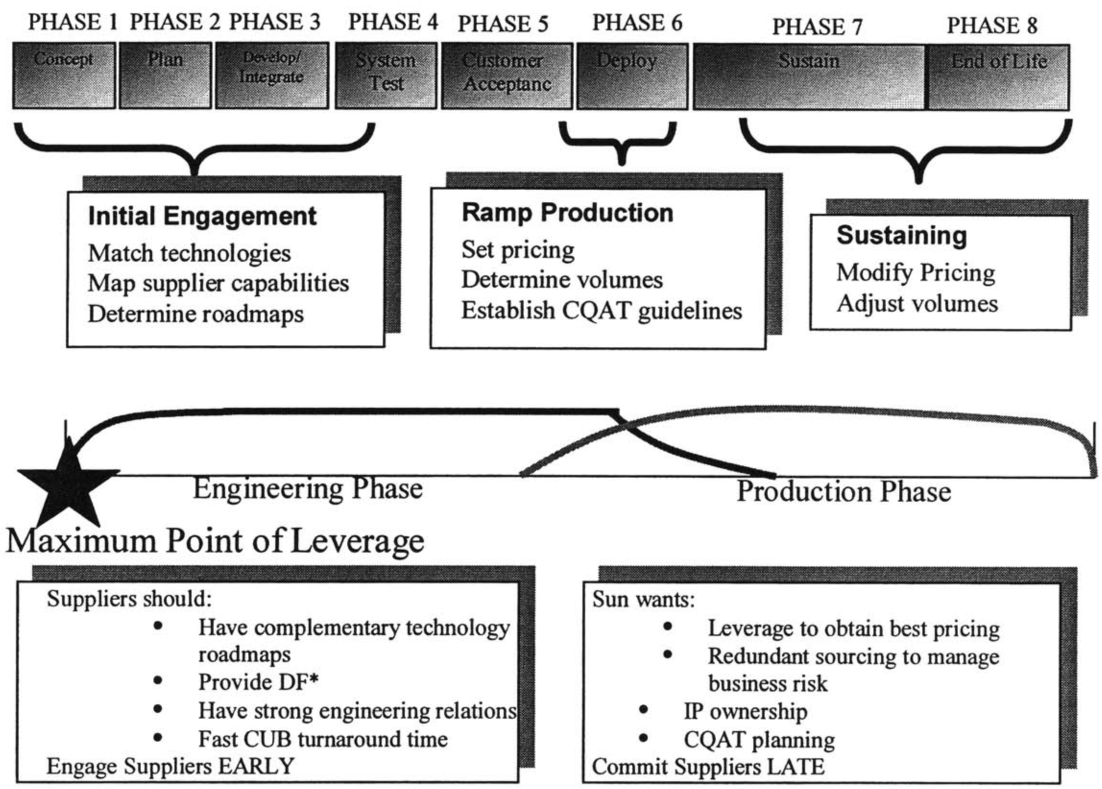


Figure 6-2: Two Phases of Supplier Relations

6.1.1 Engineering Phase and Initial Engagement Negotiations

Figure 6-2 indicates three types of negotiation that occur during the product life cycle. The first negotiation occurs very early in the product life cycle. It is generally done before there are specific production volumes or defined specifications. It marks the beginning of the engineering phase of the relation. The selection process is focused on finding the supplier who is best aligned to help Sun meets its design requirements. There is effort to identify complementary roadmaps and technological capabilities that match the needs of Sun for the given design. Other important factors are how well the supplier works with Sun engineering, how fast they can produce prototypes and assess the impact of Sun specified changes to the specifications, and are they able to make contributions to improve on Sun's design and enhance the manufacturability of the part.

6.1.2 Production Phase and Volume Product Negotiations

The production phase of the relationship, shown in Figure 6-2, begins during the ramp of production and continues until the end of the product life cycle. During this phase there is an increased focus on cost, quality, availability, and time to market goals. A typical supplier strategy is to provide significant engineering effort during the first phase and lock in their right to provide volume during the production relationship. The supplier attempts to re-coup the costs from the engineering phase during volume production.

The nature of the relationship changes over the product life cycle; the amount of leverage that Sun controls also changes over the product life cycle. Once a supplier is selected and producing at volume, the cost and risk of switching to a new supplier increase. There are also intellectual property (IP) issues that can arise post-production. These issues lead to a loss of leverage.

The amount of leverage that is lost is dependent on the commodity. For a commodity such as enclosures where there are high tooling costs or ASICs where suppliers often own some of the technology IP, the lost leverage is considerable. In commodities like printed circuit boards, where the switching costs are lower, the lost leverage is less. Regardless, there is still some loss of negotiation leverage held by Sun after a supplier is selected.

6.1.3 Maximum Point of Leverage

Figure 6-2 shows that the maximum point of leverage for Sun exists before Sun has committed to any supplier. At this point, the suppliers are anxious for business and willing to provide concessions to secure production rights. Unfortunately, this point of engagement often occurs during the first negotiation process before the design requirements, volume production, expected pricing, and exact nature of the production relationship are known. It is difficult to negotiate on parameters that are still evolving or poorly defined. Any price agreements will be changed as the product evolves. What is known at this time is the type and extent of engineering collaboration that is desired from the supplier. It is natural to focus on these parameters since they are known and the most pressing at the time of engagement.

Focusing only on the engineering relationship at the maximum point of leverage leaves Sun vulnerable during future negotiations. Prior to the production phase, a savvy supplier will attempt to provide some lock-in mechanism, such as IP ownership, to insure they will receive their expected volume production at their desired price. The supplier has more leverage after providing engineering support.

6.1.4 Balancing Leverage and Collaboration

The loss of leverage could be viewed as the price a firm must pay to enjoy a strategic relationship with suppliers. Collaboration will have a cost associated with it. There is not a formula to determine the amount that must be paid for this trust and collaboration. Suppliers have motive to make it as large as possible without severing the relationship. Buyers have motive to make it as small as possible without severing the relationship. How much the relations will cost depends on who has the greater leverage during negotiations. Given the situation outlined in the previous paragraph, the leverage will tip to the suppliers during price negotiations.

The loss of leverage is not a fundamental characteristic of the relationship. It was the result of unclear production requirements and specifications at the point of maximum leverage. It is unrealistic to define clear production requirements during the early engagement. However, it is possible to design a leverage structure during this early phase. A supply chain leverage model will not instantly give a buyer leverage over suppliers, but it will create a framework to understand what conditions need to be included to minimize the loss of leverage.

6.2 Supply Chain Leverage Structures:

The term *supply chain leverage structure* refers to how a buyer and seller negotiate and what mechanisms are used to maintain leverage. There are three fundamental structures that are used within Sun (and other companies that were looked at for this research). They are: a single source model, a closed sourced model, and an open source model. The models are presented in a fairly generic nature. There are many alterations and derivates that can be made to the models. At a high level, most relationships can be classified into one these three structures.

6.2.1 Single Source Model

As the name implies, this is when a single supplier is chosen as the sole source for a product or service. Typically there is some form of selection event to initially choose a supplier, after which that supplier remains the sole source. During the life of the product, pricing and volumes are renegotiated with that supplier. How the price is negotiated varies, Two common formats are a manual negotiations and cost targeting. Figure 6-3 is a visual representation of this leverage structure.

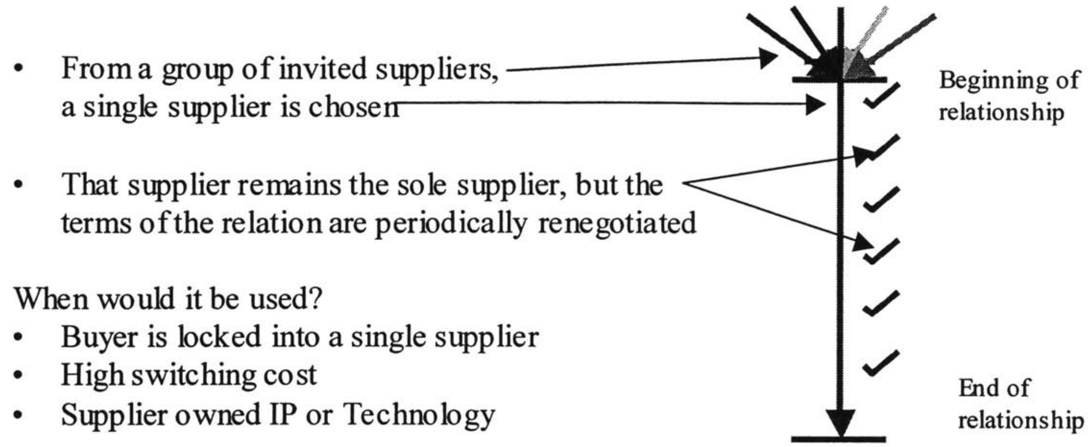


Figure 6-3: Single Source Leverage Structure

This model is typically seen in two situations. First, when tight relationships are required between the buying firm and supplier. This could be the effect of collaboration or the need for technological capabilities. The second case is when a supplier has monopolistic power over the buyer. Once in a single-source relationship, much of the leverage is removed from the buying firm. The supplier is able to extract higher prices because the buying firm is locked in. The source of leverage the buyer has is when the supplier is first chosen.

Buyers don't enter this model for cost saving incentives or risk mitigation. It is difficult for a buyer to obtain best in class pricing using a sole supplier, and it leaves the buying firm exposed to supply shortage risks. However there are many other reasons that might justify a firm entering into this model. The value of collaboration, reduced costs from outsourcing the design, the ease of dealing with a single supplier, the supplier owns IP that has design value, there are extremely high fixed costs, or there is a sole supplier with the needed technology are a few reasons. Trade-offs must be made to determine if the value added from supplier contributions justifies the additional premium paid for the goods. Before that trade-off should be made, the main factors contributing to the decision need to be carefully looked at to see if they can be satisfied with another leverage structure.

6.2.2 Closed source model

This model is characterized by a fixed set of two or more suppliers who produce all of the volume for a part. A selection event occurs to initially select the set of suppliers to provide productions from the entire pool of potential suppliers. Once this set of suppliers is selected, the actual production volume each supplier is awarded is determined by a set of metrics chosen by the buying firm. They typically include cost, quality, availability and other key factors. These volume splits are adjusted periodically throughout the life of the product based on the supplier's willingness to meet the metrics set forth by the buyer firm.

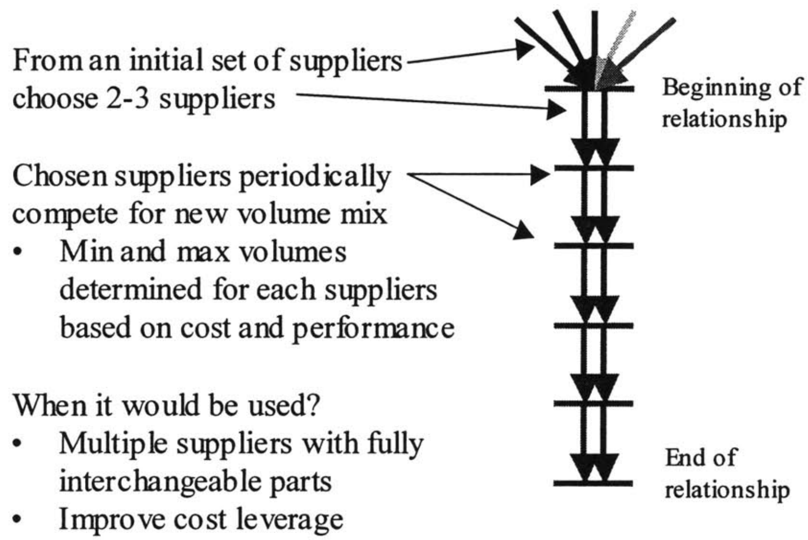


Figure 6-4: Closed Source Leverage Structure

Figure 6-4 shows a graphical representation of this leverage structure. The following is an example of how this might work. Given 10 possible suppliers, a buying firm might chose suppliers A and B to produce the product. From this first selection event, Supplier A might be awarded 65% of the volume while Supplier B receives 35% of the volume due to price and quality differences. After a quarter, Suppliers A and B are compared again (perhaps through a dynamic bidding event). Supplier B has greatly improved its cost and quality, while Supplier A has maintained its previous position. Supplier A and B are now given 50% each of the volume production. This process would repeat itself on a periodic base throughout the life of the product.

This model allows the buying firm to retain a large degree of leverage over the suppliers and to mitigate its supply risk. It affords suppliers a level of stability and predictability that is valuable for preserving supplier relations. These features make this an attractive leverage structure. To obtain this model requires upfront planning. It requires that the parts from different suppliers be completely interchangeable. This can be hard to arrange making this model difficult to implement. To maximize the buying firm's leverage, the suppliers need to be competitive in both cost and capacity. A second supplier that can only support 15% of the total volume or has 50% higher costs does not create significant competition for the dominant supplier.

Other computer manufacturers use a similar model, though not necessarily implemented with a reverse auction. The leverage for this model is obtained though competition. Any form of collusion by the suppliers could bypass that competition and render the model ineffective.

6.2.3 Open source model

The open source model is based on open market price negotiations. All qualified suppliers are invited to participate periodically in a selection event to choose which supplier will provide production volumes for the period. Past relationships are not a guarantee or indication of future contracts. This model is often seen in pure commodities. Figure 6-5 represents this leverage structure. This is the model where reverse auctions are typically used in industry.

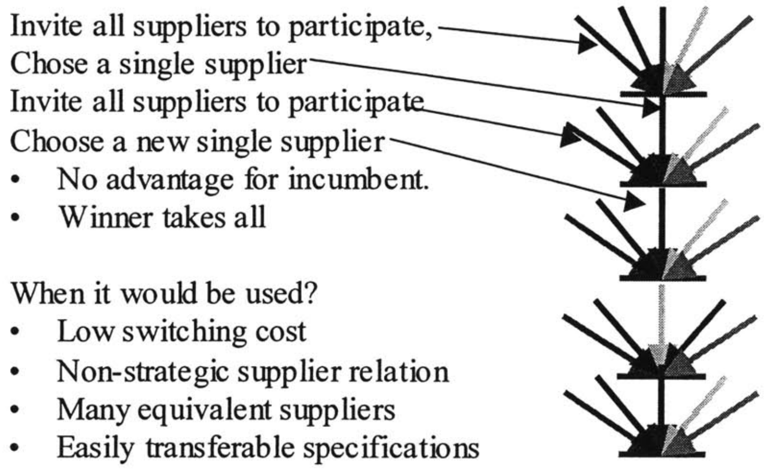


Figure 6-5: Open Source Leverage Structure

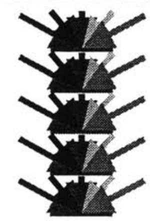
An example of the open source model might be seen buying raw steel on the open market or buying gas at an intersection with four gas stations. In both cases, the product itself offers very little differentiation and suppliers are forced to compete, often on price, to win business.

Due to the intense competition this type of structure creates, the buyer firm has a great deal of leverage at the point of negotiation. It can use this leverage to obtain best in class pricing as well as other quantifiable sourcing requirements such as quality control. This leverage is the primary advantage of this model. The relationships with suppliers in this structure are short lived. Without long- term expectations, suppliers must extract as much value from the relationship as they can in the given contract period.

The relationships in this structure are typically governed by contracts with a lower degree of trust than a long-term relationship might enjoy. It is up to the buyer firm to anticipate their needs properly and communicate these needs to the suppliers in the contract. Suppliers do not receive many benefits from this model; it is therefore unreasonable to expect a high level of supplier willingness to help beyond the terms specified in the contract. A supplier might help to convince the buyer that they provide value beyond the contract and therefore should not be subject to this type of leverage structure. However, this supplier behavior should not be expected to last indefinitely.

The open source model requires low switching costs between suppliers to be effective. It also requires the buyer firm to have complete specification and IP ownership of the product. A large supply base of reasonably equivalent suppliers increases the effectiveness of this model. Table 6-1 summarizes the basic characteristics of each of the structures.

Table 6-1: Summary of Leverage Structures

Models			
Trade-offs	Low leverage Trust	(Negotiations) (Relationships)	High Leverage Contractual
Typical Conditions	•Single supplier •Non-sun IP ownership •High tooling costs, low volumes	•Multiple suppliers •Interchangeable parts	•Large supply base Equivalent capabilities •Low transfer costs •Non capacity constrained market •Full IP and spec ownership

6.3 Decision Flowchart

Understanding the leverage structures is just the first step. The next step is to fit a supply chain leverage structure to a product based on its design and production requirements. The structure used is related to other design choices. By understanding the relationship between supply chain structures and design decisions, an optimal structure can be used for a given set of choices.

While considering all the possible trade-offs would be overwhelming, there are four simple design questions that can be used as a foundation for an initial decision for which supply chain structure is most suitable. These questions assume that the actual manufacturing will be outsourced.

- What is the level of collaboration needed/wanted from the supplier?
- What is the status of the specifications when the supplier will be engaged?
- Does the buyer want to multi-source in production?
- Does the buyer want to multi-source in development?

Figure 6-6 shows a flowchart which can be used to select a leverage structure based on the result of the four questions outlined above.

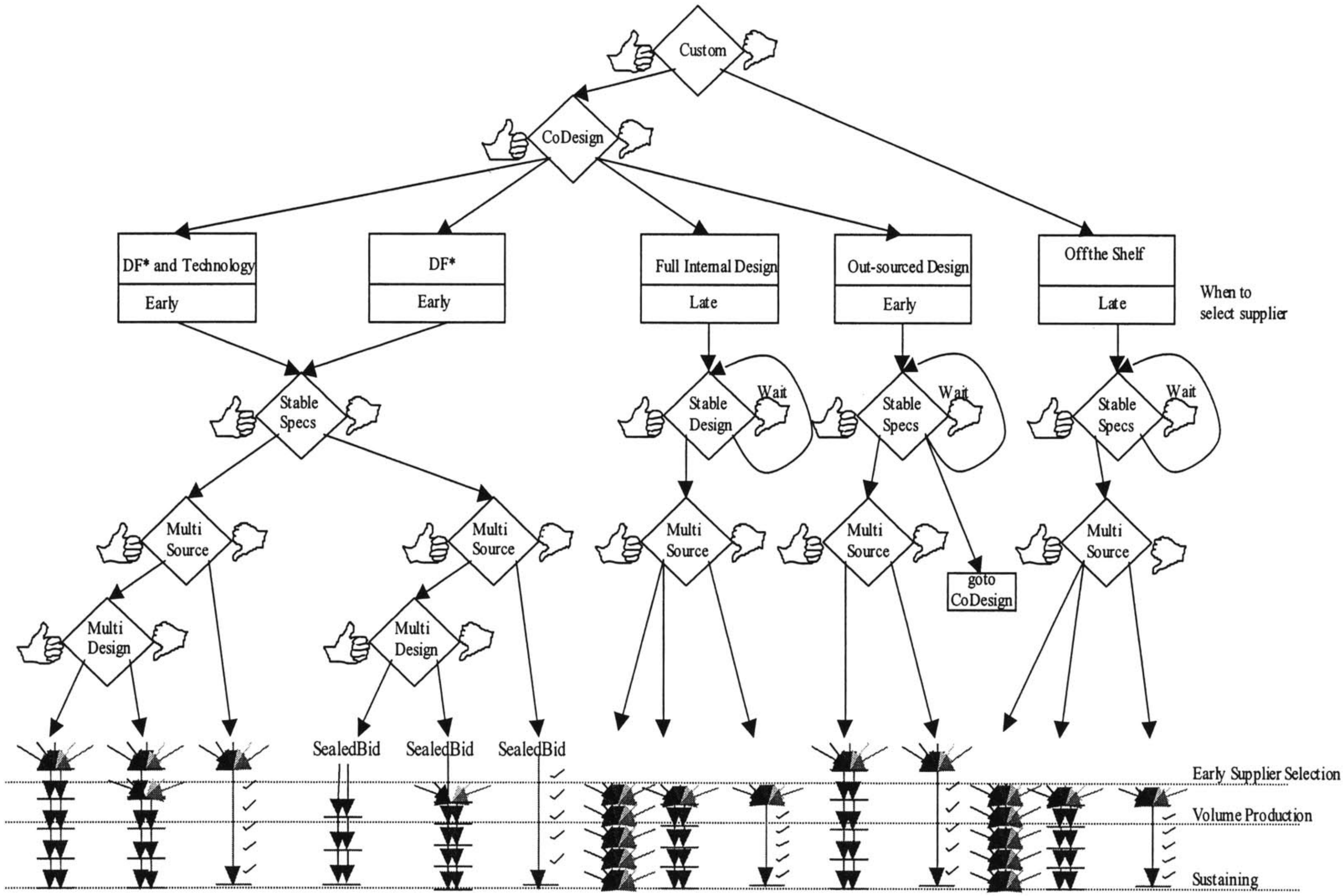


Figure 6-6: Supply Chain Leverage Structure Flowchart

6.3.1 Collaboration between the buying firm and the suppliers

The first decision in the flowchart is how the product will be designed. Figure 6-7 contains this portion of the flowchart. How the product will be designed is captured in two questions: is the part custom or off the shelf and will the part be co-designed? There are four basic models for designing a new product: in-house custom design, outsourced custom design, outsourced off the shelf or some level of collaboration between the firm and one or more suppliers. The flow chart distinguishes between two levels of collaboration. One level only requires design help; the other level requires design and technology. The distinction is made to draw attention to how reliant the buying firm is on the supplier. Understanding the level of reliance helps determine the amount of supplier willingness needed in the supplier relation.

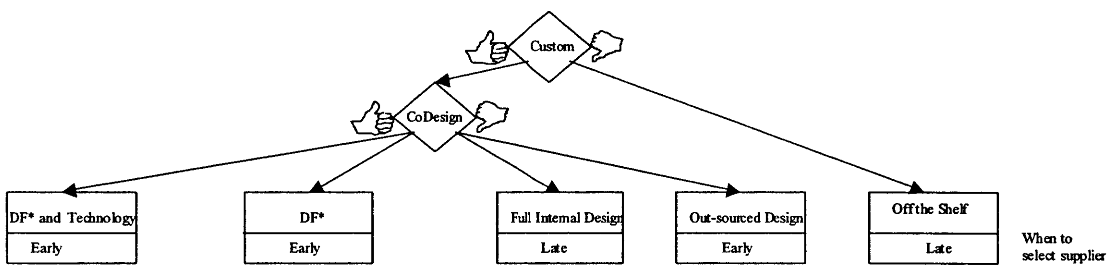


Figure 6-7: Collaboration Decision

An in-house design and an outsourced design can both be handled in a similar fashion, though at different stages of the product life cycle. In either case, the complete project can be handed off to a supplier who must assume full and complete responsibility for it. With the outsourced design, the supplier would receive high-level design requirements and would be responsible for translating those requirements into a detailed specification and likely be responsible for building the part to those specifications. They would be chosen early in the design process. With the in-house design, the supplier would be engaged late in the design process and would receive the final specifications. They would be responsible for building the part to those specifications. In both of these situations, there are clear boundaries of ownership and accountability. This provides a convenient framework for monitoring suppliers in the leverage model.

Collaborating with suppliers on the design distorts the lines of ownership, but offers many advantages including supplier expertise, design for manufacturability, testing, assembly, etc (referred to as DF* within Sun). Given the advantages, it is not surprising that this is the most frequent type of relationship between Sun and its suppliers.

The types of relation and the time to engage the supplier are important criteria to selecting a leverage structure. Once they are determined, the next step is look at the specifications.

6.3.2 Status of specifications

The stability and clarity of specifications at the point of supplier selection is another critical parameter to consider. If the specifications (or design) are very well understood and fixed, it is easier to use an out-sourced or in-house design. If specifications are still fluctuating at the point of engaging the supplier, the level of collaboration must increase while the changes are incorporated. Figure 6-8 shows the decision flow for specifications.

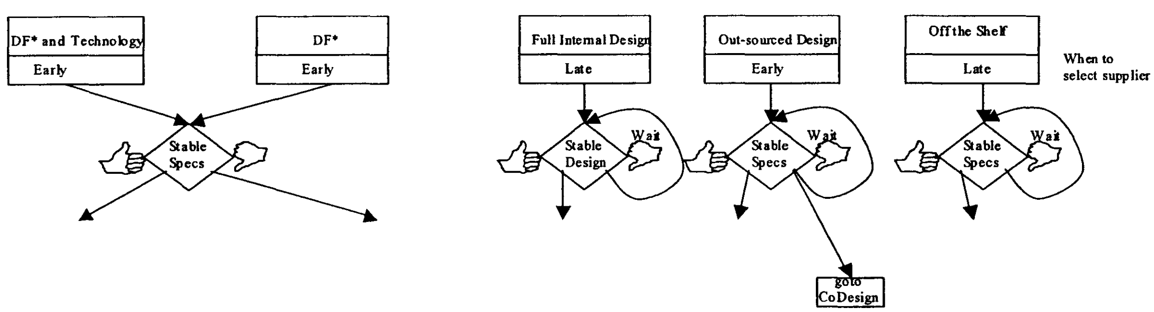


Figure 6-8: Stability of Specifications

As discussed in chapter 5, the nature of the specification creates two important issues that must be considered. If the specifications are not well defined during supplier selection, suppliers must make assumptions. As soon as this occurs, the equality of comparison between suppliers is gone allowing subjective decisions and potential deception. The second issue is maintaining a price after the supplier is selected. Suppliers can leverage changing specifications to increase their prices. The level of effort to maintain best in class pricing increases with the number of changes made to the specifications post event.

The in-house, outsourced, and off-the-shelf design flows all require the specifications to be stable before a sourcing decision is made. This does not mean that absolutely no design changes should be made after the sourcing decision, but rather that there should be a minimum amount. If an extensive amount of changes are expected, the sourcing decision should be delayed until the specifications stabilize. If an outsourced design is desired, but the buyer wants to change the specifications through the design, this creates a similar situation to a co-designed project and should be treated as such.

6.3.3 Multi-source in production

The previous two sections dealt with the design of the product. Once these decisions are made, basic sourcing decisions can be made. The first of these decisions is the how many suppliers are desired during production. Most companies desire to multi-source in production for risk mitigation and to maintain leverage over suppliers. At first glance it seems that the answer to this question should always be to multi-source. However there are various factors that can remove a buyer's ability to multi-source. Figure 6-9 shows the flowchart for this part of the decision matrix.

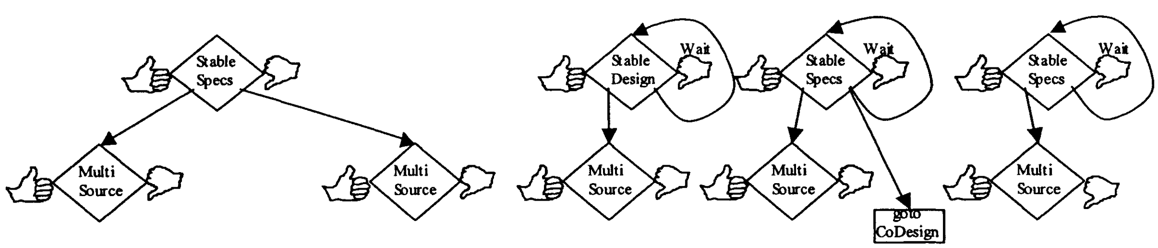


Figure 6-9: Multi-source Production Decision

The question is not what sourcing decision would be ideal in a perfect world but rather what is best for this product and the current situation. Many of the multi-sourcing blocking factors can be controlled though planning, some cannot. Some key factors to consider:

1. How many suppliers have the necessary technology?

2. Can the buyer firm maintain complete ownership of the specification?
3. Will the buyer firm own all the intellectual property for the design?
4. What are the overhead/tooling costs for production?
5. Will the parts be interchangeable from different suppliers?

Regardless of the previous design decisions, the choice of multi-sourcing is available. If the multi-source decision is planned from the beginning, the nature of the supplier relation can be maintained to allow multi-source. If the decision is delayed, suppliers often create mechanisms to achieve lock-in (such as IP ownership).

For non-collaborative designs, this is sufficient to choose a leverage structure; for co-designed parts, there is another question- whether to multi-source the development.

6.3.4 Multi-Source in Development

The Multi-source development question is separate from multi-source production question. It is possible to have a single supplier help design the product, but then have two suppliers produce the product. It is possible to have two suppliers develop the product simultaneously and then have both supply the product. It is also possible to have two suppliers develop the product, and then choose only one of the suppliers to produce it. While this last case has been observed in some large items such as silicon testers and jet engine development, it is a fairly rare occurrence and typically requires a great deal of supplier power to use it. It is not included in this flowchart as an option. Figure 6-10 shows where the multi-design decision fits into the flowchart.

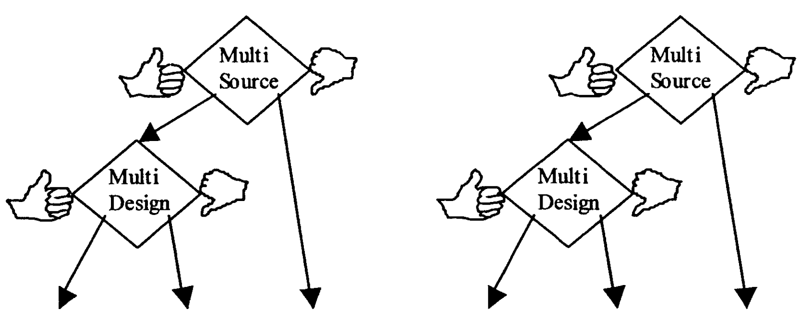


Figure 6-10: Multi-source Development Decision

When making the multi-design decision, there are a number of factors that should be considered. There are both advantages and disadvantages to multi-developing. The best solution depends on the part and circumstances.

The advantages to multi-developing are:

1. Discourages a single supplier from owning Specifications and IP
2. Leverages design knowledge from two suppliers
3. Easily transitions to multi-production

The disadvantages to multi-developing are:

1. Potential conflicts in design trade-offs between suppliers
2. Increases risk for incompatibility between parts
3. Increases the engineering expenses and overhead to maintain consistency between designs

6.3.5 Choosing the Leverage Structure

Each of the four questions in the flowchart influences the optimal supply chain leverage structure for the given product and situation. The structures shown in Figure 6-11 are suggestions and should not be taken as the only solution.

There are various forms of leverage structures presented here. They are derivatives of the three structures presented earlier in this chapter. The phases of supplier relation for the product life cycle is broken into three segments: early supplier selection, volume production selection, and sustaining mode. These phases could each be handled differently depending on the situation. Each model suggests how to design the supply chain to manage suppliers during the three phases.

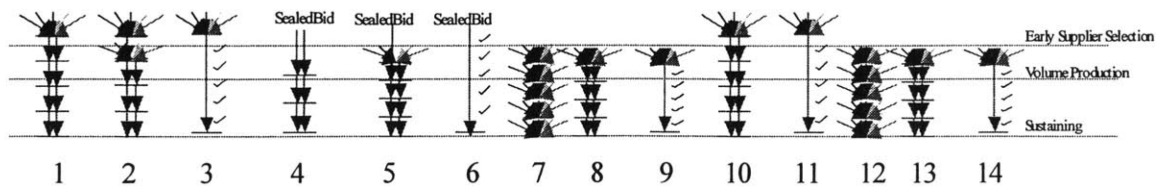
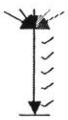


Figure 6-11: Variations in Leverage Structures

Structure 3, 9, 11, 14: Single Supplier model 

Start with an open dynamic bidding event to select a single supplier and then continue with periodic cost reductions with that sole supplier throughout the life of the product. In Models 9 and 14 the supplier selection is delayed until volume production. In these cases, there is no collaboration during the design phase so suppliers do not need to be included early. Models 3 and 11 require early supplier selection since the supplier will be involved with the design. In both cases the specifications are stable and therefore the supplier can be selected using a cost based tool such as dynamic bidding.

Structure 1, 8, 10, 13: Dual Source model 

Start with an open dynamic bidding event. From the event, choose two or more suppliers. In subsequent DB events only the chosen suppliers are invited and their volume is adjusted to reflect their cost reductions and overall performance. Models 8 and 13 have delayed supplier selection until production because there is no reliance on supplier for design help. Structures 1 and 10 require early supplier selection, but suppliers will be given stable specifications. Model 1 is a dual source and dual design solution. Both suppliers go through the design phase and both are involved in producing the part. This is similar to model 10, where the entire design is outsourced to two suppliers. Each will design to the specification and produce the results. Model 10 is susceptible to incompatibility between the parts. A very detailed specification is needed to use this model.

Structure 7, 12: Open DBE model 

Periodically conduct open bidding events. Each event is open to all qualified participants. The incumbent is given no guarantee or preference for future business. This model requires the design be complete and easily transferable. It can be used in off the shelf parts and some internally designed parts.

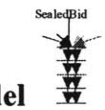
Structure 2: Single-source Develop/Dual-source Production model 

Conduct a bidding event to choose an initial developer to participate in the co-design effort. A bidding event can be used for the development partner because the specifications are stable. At production, conduct a second bidding event to select an additional supplier(s) for dual sourcing through production. To make this model work, it is vital that the original supplier understand that they will not be the sole supplier. The first supplier may or may not be involved in the 2nd bidding event. They could be guaranteed a percent of the production if incentive is needed or subject to the bidding where their result is based on how they compete in the bidding event.

Structure 4: Sealed Bid, Dual Source model 

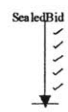
Conduct a sealed bid event and choose 2 suppliers to help in the development and production. The use of the sealed bid instead of the dynamic bidding event reflects the fact that the specifications are not stable. Competing on price at this stage can cause strain in the relationship without any benefits since the early agreed upon price was an estimate at best and will change dramatically as the specifications change. A sealed bid still puts pressure on suppliers to offer competitive pricing but they are able to make their decision without the real-time pressure from other suppliers. (Sandy Jap's research found that supplier relations were less strained as a result of a sealed bid compared to a reverse auction.[29]) Once production is reached, a closed dynamic bidding structure can be used to determine volume splits between the suppliers.

Structure 5: Sealed Bid, DBE, Dual Source model



This structure is very similar to structure 2. It is used when a single supplier will collaborate during design, but multiple suppliers will be used in production. The difference is the state of the specifications. Because the specifications are not stable, a sealed bid is used to select a development partner. A price based selection process is not effective without stable specifications. At production, a bidding event is used to select the second source. For the rest of the product life, the selected suppliers are involved in bidding events to determine volume splits.

Structure 6: Sealed Bid model:



This model is the same as the sole source model, except the original event is a sealed bid and not a bidding event. The use of a sealed bid is related to the instable specifications. The price in this model will be tough to manage. There should be explicit trade-offs to justify the use of the model. Given this is the model that will be used, considerable effort should be made to include requirements in the sealed bid for managing the price with the supplier throughout the life of the product (such as a costed BOM or Guaranteed cost reductions).

6.4 Limitations to the Leverage Structures Model

The flowchart is not meant to be an absolute determinate for the supply chain structure, but rather a guide and framework to allow key stakeholders to use a common language and context for discussing trade-offs. As discussed at the beginning of the chapter, the two phases of supplier relations, the engineering and production phase, are often dealt with separately. By looking at both phases before engaging suppliers, as suggested by the

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[29] Sandy Jap, The impact of Online, Reverse Auctions on Buyer-Supplier Relations, July 2001

flowchart, a buyer is able to maintain greater leverage and prevent mis-communication of expectations. The free flow of information and expectations plays as critical a role in managing the supplier as does the actual structure used.

While designing a leverage structure can aid in obtaining better results from a bidding event (as well as improving other sourcing structures). It is not the only factor that plays a role in determining result. There are other internal and external factors also play an important role. One of the external factors, industry trends, is looked at in the next chapter.

7 INDUSTRY TRENDS

There are various factors that Sun can adjust to improve the value of dynamic bidding such as better control of specifications and increased communication about the nature and type of leverage structure they are using to manage costs (as discussed in the previous chapter). There are many factors that are out of Sun's control. These factors should be monitored even if they cannot be controlled. One of the factors is how reverse auctions are perceived in industry and what is the overall adoption rate of reverse auctions.

While some suppliers benefit from reverse auctions and certain industries are accustomed to this type of competitive cost pressure, the majority of suppliers do not view reverse auctions as beneficial to their business models. Pembroke Consulting predicts that one of the five major supply chain trends during 2002 will be: "Savvy suppliers either opting out of reverse auctions or developing counter strategies like alliances, market differentiation, and bundling value-added services" .[30] This is based on research conducted for the National Association of Wholesaler Distributors as well as its own market research.

The ability for suppliers to opt out of reverse auctions is related to the overall adoption rate. If only a single buyer uses auctions, suppliers might be willing to walk away from the relationship to avoid auctions. If auctions are used extensively by a majority of the buyers in the market, suppliers will have fewer options and may not be able to simply walk away. As reverse auctions hit a critical adoption rate, they are much more likely to become business as usual.

The following chapter looks at the current adoption trends in the high tech industry and other industries.

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[30] Press Release, *Pembroke Consulting issues supply chain watch list for 2002*, Pembroke Consulting, Dec 17, 2001

7.1 Industry Adoption of Auctions:

An increasing number of companies are using auctions to obtain pricing on goods and services. Deloitte Consulting conducted a survey of over 125 global corporations in the winter of 2000. They found that 31% of the polled companies were currently using reverse auctions with an additional 24% indicating that they planned on using auctions within the next 12 months.[31]

An analysis of when companies first announced the use of auctions reveals that there is a lag in the high tech sector for adoption of auctions compared to the older/slower-growth manufacturing firms of about 12 months. Figure 7-1 shows the months relative to November 2001 since companies announced the use of reverse auctions. (Data gathered from public announcements and informal information exchanges, in some cases the author made approximations. If an exact month was not known, the average of the year was used instead and is indicated on the chart with a 12-month range.)

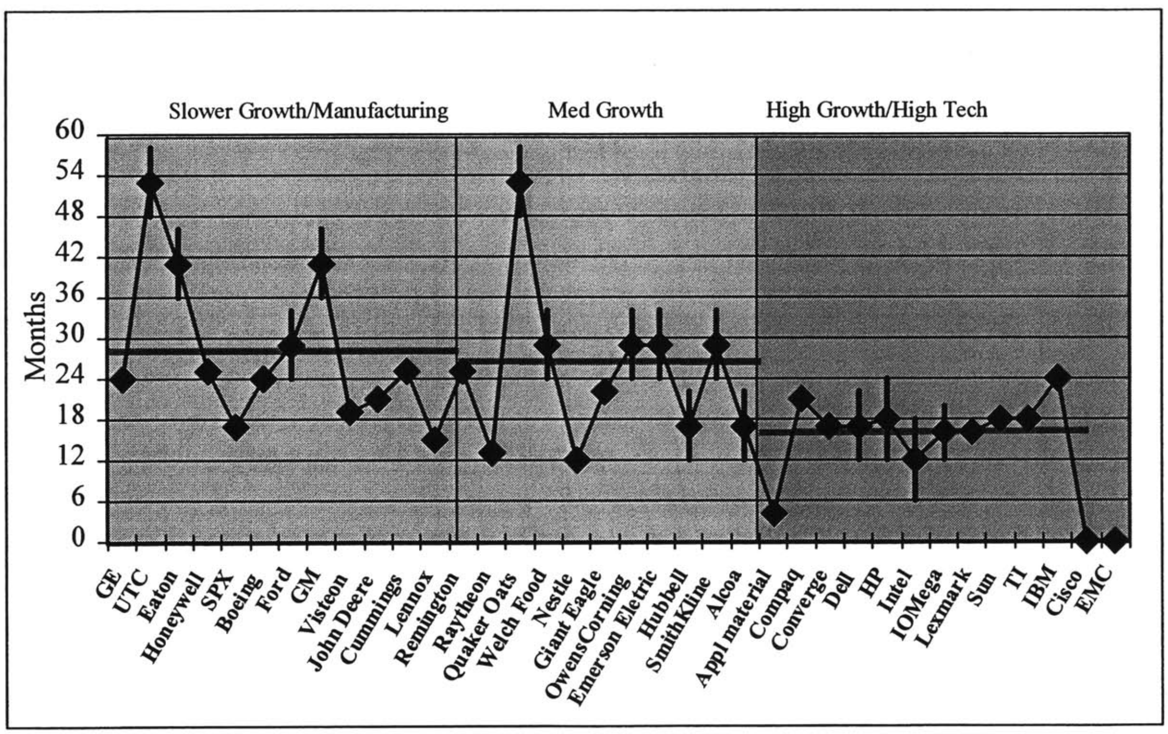

Figure 7-1: Industry Adoption of Reverse Auctions (As of November 2001)

[31] Realizing the Vision of B2B procurement, Deloitte Consulting, Jun 2001, pg. 12.

The lag in adoption of high tech is attributed to a difference in focus between older manufacturing firms and high-tech firms. High tech tends to focus on revenue growth through market expansion. Slow-growth manufacturing focuses on cost-efficiency and cost-reduction. Cisco Vice President, Tom Vallon explained their high tech philosophy:

> "We understand risk and reward and what we value, and what we value most is time- The ability to execute new products and to change quickly. What's more important: perfect execution or driving down our supplier margins to the lowest possible level? We always say the value to us is in time and technology." [32]

This philosophy is in stark contrast to the response of a large conglomerate using reverse auctions. They indicated in a discussion with Sun that their bottom line is cost reduction and a supplier who is not willing to reduce costs is not going to last as a supplier. Though the company recognized that strategic relations are vital; these relations maintain a focus on obtaining the best pricing.

While high tech appears to be lagging in adoption, the industry is experimenting with reverse auctions. Large corporate peers have recently approached Sun to learn more about the process. Most of the high tech companies contacted for this research were using or considering using reverse auctions. The follow section contains a summary of the findings from other high tech companies.

7.2 Reverse Auctions in High Tech

High tech companies are using reverse auctions. However, most have not disclosed the exact details of their use. Table 7-1 contains some general information gathered from web articles. It provides an estimate of what industry leaders in high tech are doing regarding reverse auctions.

[32] Timothy Laseter, Balanced Sourcing-Cooperation and Competition in Supplier Relations, Jossey-Bass Inc., 1998, pg. 234-235.

Table 7-1: High Tech use of Reverse Auctions

(Data acquired Sept –Nov 2001)

Company	Estimated Actively Auctioning	External Service Auction Offerings	General message
Sun	Yes	I-Planet	Actively promoting benefits and savings
HP	Yes	Converge	No public information on use, but supporting Converge, suppliers verify HP has used reverse auctions
IBM	Yes	Websphere	Selling service, but no public announcements of internal use. Estimated about 2 years experience.
Compaq	Yes	Compaq Global Business Exchange with CommerceOne	Compaq India and UK have used them
Dell	Tried , stopped direct goods, continue in indirect goods	None	Tried Freemarkets, concluded other tools were as efficient
Intel	[redacted]	None	Believe they get best pricing already. Looking into value of reverse auctions.
EMC	[redacted]	None	EMC does not use reverse auctions.

It is not known if the high tech industry chooses not to disclose their use of reverse auctions because they are unsure of the long term value, they have not seen positive results, or if they view their implementation as a strategic advantage.

7.3 Predictions for the Future of Reverse Auctions

There is a great deal of uncertainty whether reverse auctions will become a standard sourcing tool, if they will be a passing fad, or if they will fill a minor niche. Given the recessive economic conditions of 2001, it is not surprising that the growth in reverse auctions has increased. Companies such are Freemarkets continue to grow indicating this is a valuable tool. However, suppliers do not favor the tool. If the economic conditions of the mid 90's return and capacity becomes a limiting factor for economic growth, suppliers will gain market power. This may reduce the use of auctions.

It is the opinion of the author that reverse auctions will continue to grow in use while market conditions are down. The use of auctions will then drop, but will remain a permanent tool for supply chain sourcing decisions. These predictions are based on the collective knowledge gathered in this thesis.

8 CONCLUSIONS

Sun ramped up on Dynamic Bidding in just over a year. In that time it conducted over 40 events for over 1.1 billion dollars in sourcing decisions. The overall results show significant return on investment with average savings of 30% per lot (20% overall when savings from events are dollar averaged and annualized).

There is a high degree of variation in savings between and within commodity groups. The dollar volume and the number of bidders appear to have some correlation to event savings, but there was insufficient data to determine the exact nature of this relation. The event date and contract length did not appear to be significant factors in determining the variation. No single factor was found to have a dominant correlation for percent savings. It is more likely that it is a combination of all the factors. There is not enough data yet to perform a regression analysis that includes this many variables.

Antidotal evidence gathered from interviews with Sun's sourcing owners, Sun's suppliers, and other companies using reverse auctions indicate that there are other factors important to the overall success of a bidding event. These factors include

- Internal Business Environment:
    - What is the level of control over Specification changes
    - What is included in non-recurring engineering (NRE) expenses
    - How are contracts used to manage supplier expectations during NPI
- External Risk Factors
    - Market Risk: Consolidation and market power risk
    - Supply Risk: capacity constraint risk
    - Design Risk: technology and design cycle time risks
    - Quality Risk: risk of failure

There is no direct correlation between savings and these factors. The external factors should be monitored to look for trends in the future and to minimize the negative relationship impact from dynamic bidding on Sun's supply base. The internal factors can be aligned to improve the supplier's reception of reverse auctions.

The definition of good supplier relations is choosing the right amount of supplier willingness and getting it for lowest total cost. There are two ways to build this supplier willingness. Force it through market power (forced willingness), or buy it (beneficial willingness) over time with money and trust.

Sun has typically relied on beneficial willingness to manage and maintain relationships. Reverse auctions shift that relationship towards forced willingness. The way this new relationship is managed is different from Sun traditional methods. Commodity leaders need to recognize this difference and adjust for it where appropriate.

To help make this adjustment in areas where dynamic bidding will be used, Sun should use its leverage points more effectively. There are different phases of supplier relations and different needs during each phase. The maximum point of leverage, just prior to supplier selection, should be used to manage all the phases. Collaboration with suppliers does have a cost, but exact price is not fixed and can be minimized through planning and using the maximum point of leverage effectively.

Using a supply chain leverage model will help plan for sourcing decisions for the total life of a product. The supply chain leverage structure flowchart maps different leverage models to design and production trade-offs. Using the model allows internal consistency across products and over time. The model can be communicated to suppliers and reduce the negative effects of misaligned expectations. It is not meant to be a strict guideline, but a framework that all stakeholders can understand and talk to.

Reverse Auctions have increased in use and acceptance. They continue to grow in both industry adoption and penetration within companies. Sun is one of the leaders of auction adoption and promotion. To continue on this track, Sun must adjust some of its sourcing practices to provide better communication to supplier and create a framework that is consistent with the use of dynamic bidding. Dynamic bidding will have an impact on supplier relations. The amount of negative impact can be minimized through effective communication and planning by Sun.

Appendix A. The Basic Components of a Computer

The fundamental components of a server are same as any other computer including a PC. The core of any computer system is a microprocessor (or cluster of microprocessors) connected to memory and Input/Output devices running software.

A.1 The Microprocessor

The microprocessor is the heart of any computer system. It is the *brains* inside the computer that is able to perform functions such as adding, subtracting, and multiplying numbers and loading and storing data. A microprocessor is classified by four parameters: the instruction set, the architecture, the bus width, and the clock speed.

- The instruction set is the complete set of instructions and the format for the instructions that a processor can read. SPARC, PowerPC, and IA (Intel Architecture) are example of different instruction sets.
- The architecture is how the instructions are decoded and implemented in silicon. UltraSPARC III, UltraSPARC II, Pentium 4 and Pentium III are examples of different architectures with the same (nearly the same) instruction sets.
- The bus width refers to how many bits the processor can read simultaneously (how many bits arrive in parallel to the execution unit of the processor). This determines how large of a number the processor can compute in a single action and how much memory it can access. A 32-bit processor can process up to 32-bit numbers (4x10^9) while a 64-bit processor can process up to 64-bit numbers (2x10^19). Most PCs are based on 32-bit processors while servers are often based on 64-bit processors.
- The final parameter used to describe microprocessors is clock speed. This is the rate that new instructions can enter the microprocessor. Clock speeds are constantly increasing. Today's processors have clock speeds between 500 MHz (or 500,000,000 instructions per second) and 2.2 GHz (2,200,000,000 instructions per second).

While clock speed is often used as the gauge for processor performance, this number alone can be very deceiving for processor performance. All four parameters play a very important role in determining the overall performance of any processor.

A.2 Storage Devices (Memory)

A processor is worthless without access to data. A processor gets data from storage. It then manipulates the data and stores the new data back to the memory. The ability to fetch and store data rapidly is a critical factor to a computer's overall performance. To improve the speed of accessing data, the storage systems for computers are broken into multiple stages, getting successively larger and slower the further from the processor. The three basic stages are the cache, memory (or RAM), and hard drive.

- The Cache is the fastest memory. It is tightly coupled to the processor and rather small. Because they are tightly coupled to the processor and physically close, they can run at high frequencies. Due to their size, it is not possible to contain all of the needed data, therefore a cache attempts to keep on the data it predicts will be needed soonest. This is data that has just been used or data adjacent to data that was just accessed. It is common to have multiple levels of caches referred to at the L1 and L2 caches where the L2 is larger and slower. Data is constantly swapped in and out of the caches as it is used.
- RAM (Random Access Memory) Memory is slower but larger than the cache. There are many types of RAM (SDRAM, RAMBUS, DDR RAM). Most of the RAM used in today computers is Dynamic. This means it requires power to maintain state.
- The hard drive is the slowest component of the memory system but it is the cheapest and largest form of storage. It also retains memory without power. The hard drive is cheap and large enough to store all of the data. When a program is run, it is copied from the hard drive to the RAM, then as parts of the program are needed, they are stored in the cache.
- Removable storage devices such as DVDs, CD-ROMs, Zip and Floppies are slower than a hard-drive, but offer portability.

A.3 Input devices

Keyboards, mouse are the most common input devices. Network connections and modems can also be used as input devices

A.4 Output devices

Monitors, printers, and soundcards are the most common output devices; network connections and modems can also be used as output devices.

A.5 Software

At the highest level, there are two types of software, the operation system and applications. The operation system provides the interface between the hardware and the applications and between applications. It is responsible for controlling the hardware and managing system resources. Applications provide the end-user with specific functionality.

Appendix B. Server Protocols and Configurations

The following section details how servers are designed to meet the requirements for scalability, bandwidth, and availability.

B.1 Scalability

The scalability of a server refers to its ability to meet the ever increasing the processing demands. This can be done by creating larger processors or linking multiple processors together to act like a larger processor. Both methods are used, though multi-processing is the current trend for greater scalability. A small server might have between 1-4 processors. Sun Microsystems' newest high-end server, the SunFire™ 15K supports up to 106 processors.

If a computer has multiple processors sharing a common memory, the configuration is called a multi-processor configuration, this is the configuration used in servers. There are two ways to achieve a multi-processor configuration: bus based multi-processing and switch based multi-processing.[33]

B.2 Bused Based Multi-processing:

The bus-based configuration uses a single bus to connect multiple processors to a common shared memory. It is the easiest of the multi-processor configurations to implement, but it is limited by bandwidth. This configuration leads to bus congestion and data overload as the number of processors is increased; four processors (or nodes) are typically the most this type of configuration can support effectively.

[33] Paul Krzyzanowski, A Taxonomy of Distributed Systems, Rutgers University, 2000 pg. 2.

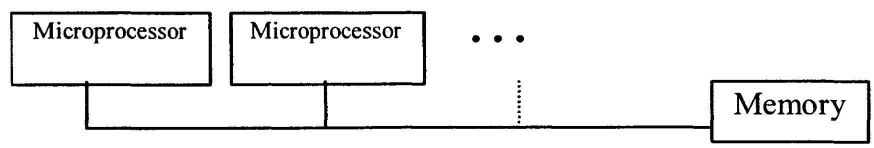

Figure B- 1: Bus based multiprocessing

To reduce bus traffic on the bus configuration, a solution is to add a local cache memory for each processor. With a local cache, the processor only needs to access the bus when the data it needs is not in the cache. While this solution improves traffic flow, it creates a data consistency problem. If processor A and processor B both access data X, then processor A changes data X, processor B now contains the wrong version of data X. One method to correct this problem is to force all writes back to memory. Caches are responsible to monitor the bus (snoop) and invalidate any local data in their cache that is being written back to the main memory. This is called a write-back cache. It improves the traffic flow on the bus while preserving data coherency.

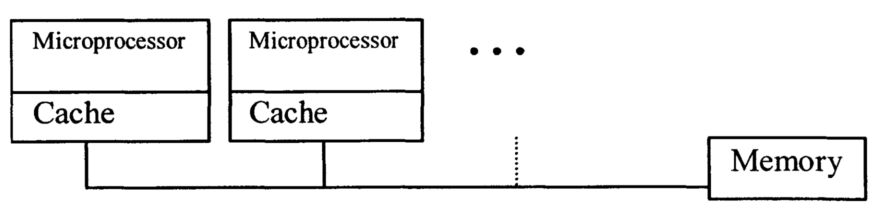

Figure B- 2: Bused Based Multiprocessing with Cache

B.3 Switch Based Multiprocessing

The bus-based system cannot handle massive multiprocessing. Bus traffic quickly reaches a point of non-usability. To connect many processors together and still maintain high data bandwidth, a crossbar switch is used instead of the bus protocol to connect the processors to memory. An NxM crossbar switch contains separate multiple crosspoint switches connected together in a grid array. It allows any of the N devices to connect to any of the M devices. To use the crossbar switch for multiprocessing, processors are placed along one access of the grid and the memory is broken into pieces and placed along the other axis. This configuration allows maximum bandwidth to each processor except when two processors are accessing the same chunk of memory.

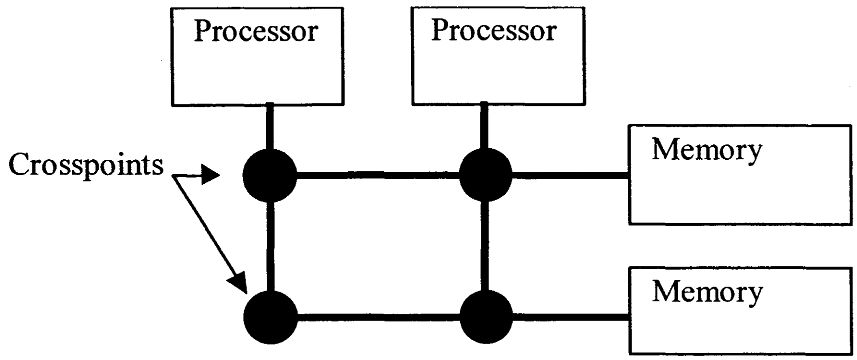

Figure B- 3: Crossbar Switch based Multiprocessing

The crossbar allows high bandwidth, but is expensive to implement. There are derivative of it that require fewer crosspoint switches. One solution is to increase the number of crosspoint switches between the memory and processor. Assuming N processors and N memory modules, a standard crossbar requires N^2 crosspoint switches but each path between memory and the processor contains only one crosspoint switch. Using a configuration called the omega configuration, the number of switches can be reduced to N*(logN)/2 switches. This configuration requires logN stages between the processor and memory. This reduces the number of crosspoint switches needed but increases the delay.

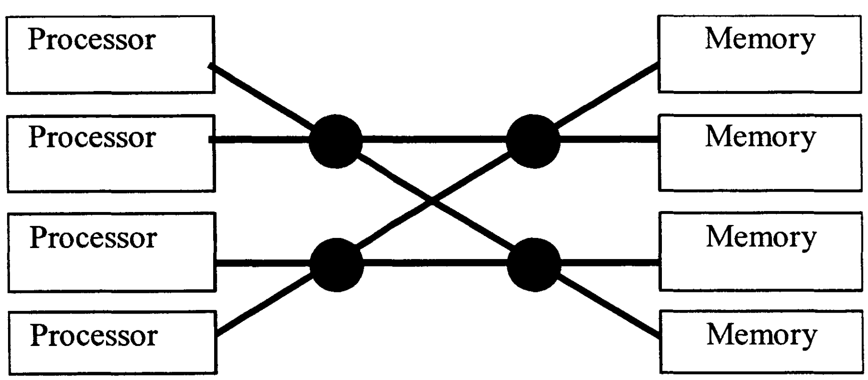

Figure B- 4: Omega Switch multiprocessing

Both the bus-based and switch based systems are considered symmetric multiprocessing (SMP) or Uniform Memory Access (UMA). This means that each processor has equivalent access and delays to memory. Many of the large multi-processor systems use a protocol called NUMA, or non-uniform memory access. This configuration uses a mixture of both the switch and bus configurations. Processors (typically four called a quad) are grouped together via a crossbar. The quad is connected to other quads via a bus. This configuration allows a processor to access the memory in its local cluster fast like a standard crossbar switch while still allowing accesses to memories outside the cluster albeit at a slower speed.

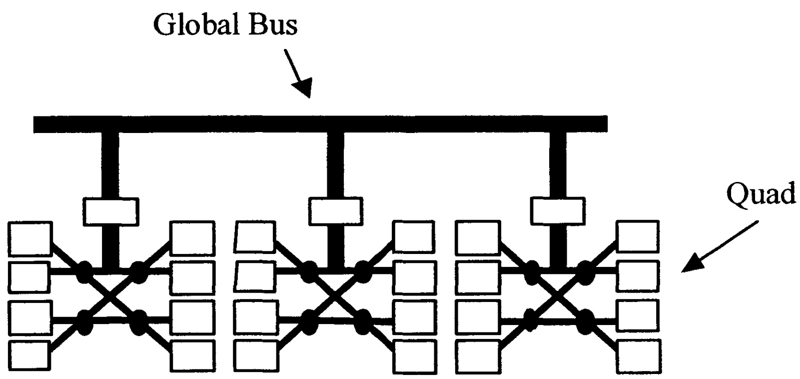

Figure B- 5: NUMA Configuration for Multiprocessing

B.4 Bandwidth

In a digital system, such as a computer, bandwidth refers the data rate or bits of data per second flowing to a given point. High bandwidth or dataflow is essential to keep processors fed with data and instructions. The crossbar switch discussed above is one method to sustain high bandwidth between local memory and processors. There is also a need for high bandwidth between peripherals and processors. There are two types of data communication protocols used between processors and peripherals: channels and networks.

- A channel provides a direct or switched point-to-point connection between the communicating devices. A channel is typically hardware-intensive and transports data at the high speed with low overhead.
- A Network is an aggregation of distributed nodes with a protocol to support interaction among the nodes. A network has high overhead since the protocol is software-intensive and is therefore slower than a channel. However it is more versatile than a channel.

Both types of connections are used in servers. The common interfaces for high bandwidth I/O devices and storage are defined below:

SCSI[34] (small computer system interface) is a parallel interface standard that connects peripheral devices such as storage to the computer. There are numerous variations to the SCSI standard ranging from 4 MB/sec to 80 MB/sec data transfer speeds. Mutiple SCSI devices can be connected to a single port making more like a network than channel.

PCI[35] (Peripheral Component Interface) is a bus standard used in PC and servers. It is a channel using a 64-bit bus, though it is usually implemented as a 32-bit bus. It can run at clock speeds of 33 or 66 MHz. At 32 bits and 33 MHz, it yields a throughput rate of 133 MBps.

Fiber channel[36] (FC) operates at four speeds (133 Mbit/s, 266 Mbit/s, 530 Mbit/s, and 1 Gbits/s) and on both electrical and optical media. The transmission distances it supports vary depending on the combination of speed and media. The protocol can be used internal to a computer or to build an external network. A storage network using FC is called a SAN (Storage Area Network). Despite the name, FC is not a channel, but attempts to captures the benefits of both channels and networks.

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[34] Definition from webopedia.com
[35] Definition from webopedia.com
[36] Zoltán Meggyesi, *Fibre Channel Overview*, http://www1.cern.ch/HSI/fcs/spec/overview.htm

Gigabit Ethernet[37] is the most recent version of Ethernet that is able to transfer data at 1 Gbit/sec. When gigabit Ethernet is used to implement a storage network it is called a NAS (network area storage).

InfiniBand[38] is an interconnect or I/O architecture that connects servers with remote storage and networking devices and other servers. It can also be used inside servers for inter-processor communication. InfiniBand is a channel-based, switched fabric, point-to-point interconnect. InfiniBand can transfer data in the range of 500 MB/s to 6 GB/s per link.

3GIO is a new protocol meant to replace PCI. It will allow asynchronous data transfers and speeds up to 6.6 GB/sec. It is not yet available.

The protocols used within a given server depend on the class of server and the expected use. Any combination of the protocol can be used.

B.5 Reliability and Availability

Reliability and Availability, though related, are not the same. Reliability is a subset of availability, availability is a common metric used to compare servers.

Reliability is based on unplanned downtime. It is the probability that a system will be work at time $t+1$ given it was working at time t.

Availability is percent of time a system is available over the total time. It includes reliability, scheduled maintenance, and repair time.

The very nature of a server implies that it is serving multiple clients. In some cases, the number of clients can be in the hundreds or thousands. Even minor downtime in a server

[37] Definition from webopedia.com

[38] Definition from webopedia.com

can cost a company a great deal in both revenues and productivity. The reliance on servers demands that they provide a high level of availability.
There are many points of potential failure within a server and various approaches to protect the system from these failures. The first line of attack against failures is to use quality parts. While this is important, it is not enough to reach the levels of availability demanded in mission critical situations. To push availability even higher, servers implement redundant systems and are designed to allow rapid repairs of failures without bringing the system down. Coupling these features with self-checks and automatic reconfigurations provides mission-critical availability.

B.6 Redundancy

The most common method to improve availability is to provide redundancy within systems. This provides a back-up in case the main unit fails. Power, cooling, some I/O cards and even some processor boards can be configured redundantly. The most common systems to provide redundancy are the power and cooling systems.

Power is a critical factor in servers. A power loss shuts down the whole system. There are two type of power loss that high-end servers protect from:

- AC power loss (such as a power black out)
- AC/DC power supply failures (local power supply failure)

To protect the system from a failing power supply, redundant power suppliers are used. For a single power supply system, this is straightforward. Adding a second power supply and bi-wire the system will provide the needed protection. However many servers require the use of multiple power supplies for normal operation. A fully redundant system is expensive, wasteful and bulky. A more common configuration is the N+1 configuration. If the system needs N power supplies for normal use, one additional power supply is added. By properly wiring the system, the whole system is protected from a single power supply failure.

To protect the system from main grid power failures like blackouts, each power supply is able to accept AC power from two sources. If one grid fails, the power supplier can draw the needed power from the other grid. One of these inputs can be connected to a local backup power supplier to remove any reliance on the external power grid.

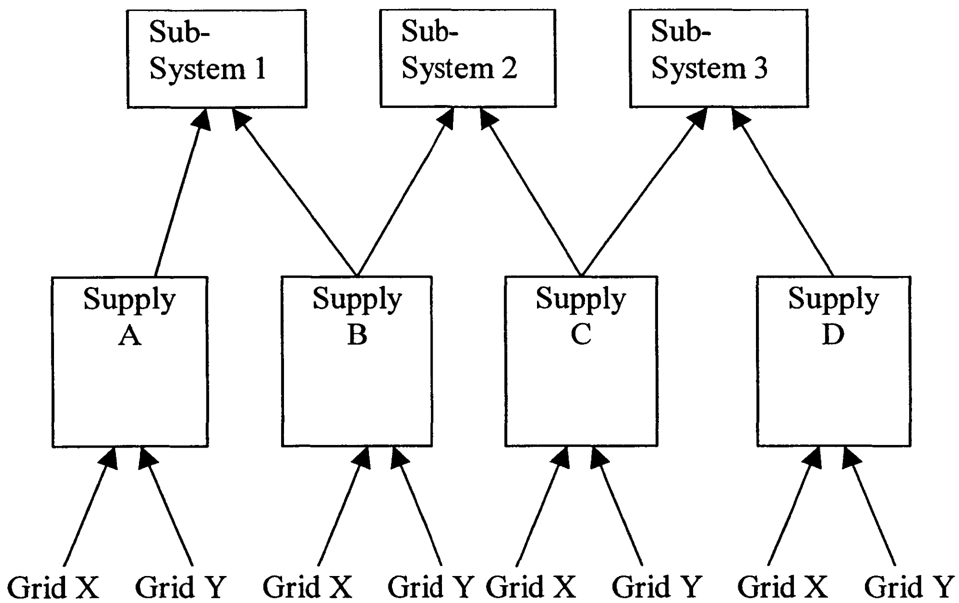


Figure B- 6: N+1 Redundancy Configuration

Cooling fans are used to maintain reasonable operating temperatures necessary for the long life of silicon and other components in the server. Redundant fans can be used for backup, the same N+1 configuration is possible with fans. An additional method employed in some of Sun's newer servers is to increase the fan speed of the remaining working fans to compensate in the case of a fan failure.

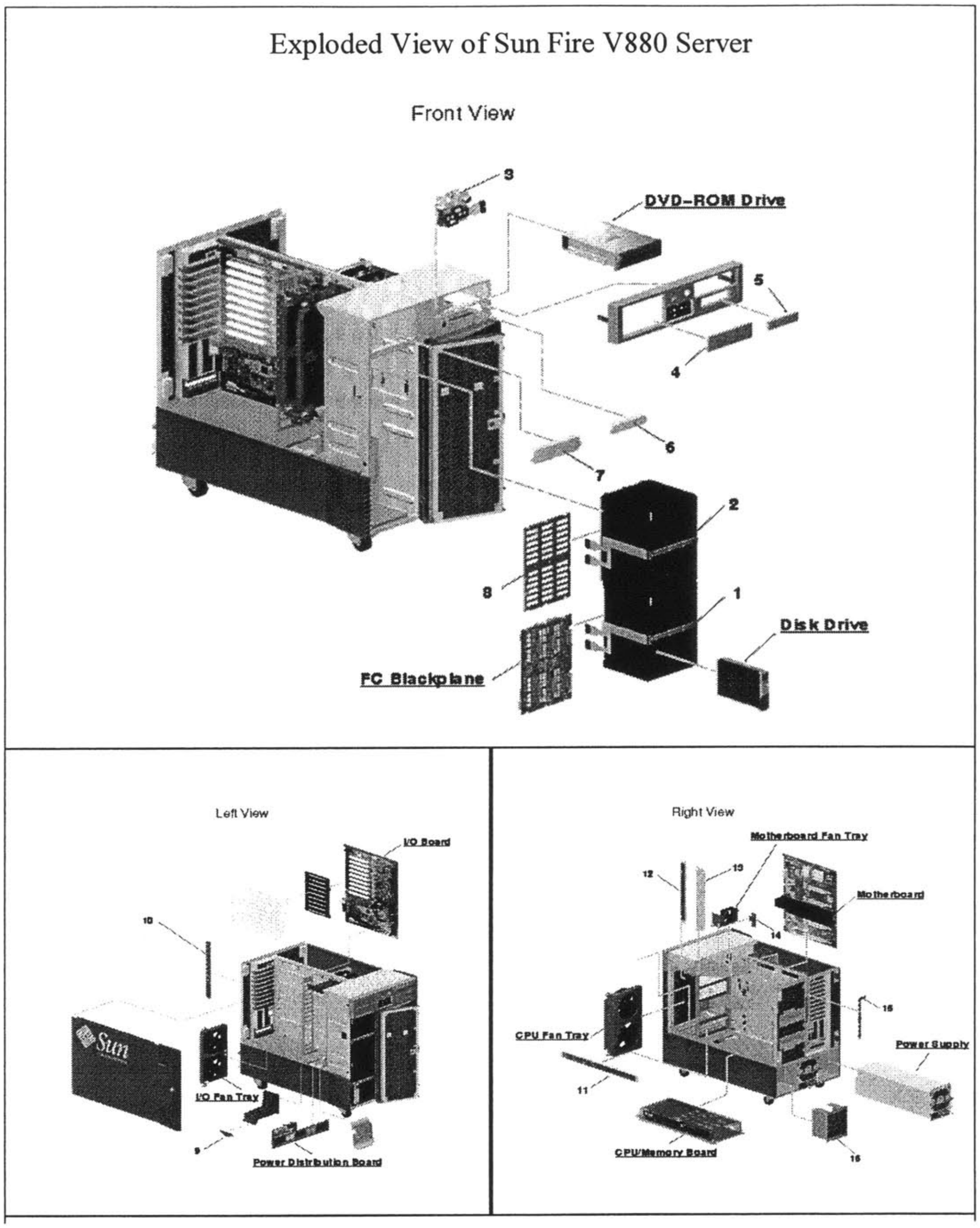
With both power supplies and fans, LED indicators are used to signal when a failure occurs. After a single component failure in fans or power supplies, the system will operate, but it is not protected from further failures until the failing component is replaced.

B.7 Hot Swapping components

To allow servers to be serviced without powering down the system, many servers allow components to be swapped while the system is still running. A component with the ability to be removed and reinstalled while the computer is running is called a hot-swappable part.

To provide seamless hot-swapping of components requires hardware redundancy. Sun systems can be configured with redundant system boards, processors, I/O controllers, power supplies and cooling fans. In a redundant system, hardware controls the enabling of the backup source. While fully redundant hardware components eliminate the possibility of a single point of failure, they are expensive and complicated. Sun uses an alterative solution where applications are made "hot-swap-aware", this allows the software to detect failures and redirect data. Using software to control the hardware reduces complexity and cost but retains the high availability associated with redundancy. Once the data is routed to alternative hardware, the failing component can be hot-swapped out while the system remains online. This software/hardware solution is called *Alternate Pathing.* To implement alternate pathing, a system must be able to dynamically reconfigure its hardware without rebooting.

Appendix C. Exploded View of SunFire V880 Server



Appendix D. Interview Questions on Dynamic Bidding

Background Information:

What is your role at Sun?
Which commodities do you work with?
What type of relationship do you have with suppliers?
How do you rate your relationship with the supplier? Friendly, Tense, frustrating, hostile?
How do you negotiate with suppliers? (What are the levers you use to push suppliers)
What factors are important when choosing a supplier?
How many suppliers do you normally consider when sourcing?
At what stage of development do you make the sourcing decision?
Do you typically single source, dual source or what?
How long is a normal contract length?
How long does it take to gather the information and make an award decision?
What process was used prior to DBEs?

Dynamic Bidding Event Information:

Which dynamic bidding event have you been directly involved with?
Rate the success of the event on a scale from 1 to 7? Why?
Rate the communication level across different Sun divisions from 1 to 7?
How valuable do you think a consist company wide sourcing process is? 1-7
Post DBE, has the relationship with the supplier changed in your opinion? How?
Was there need for post event negotiation?
What surprised you?
Would you like to use Dynamic Bidding again?

General DBE info:

What is your opinion of dynamic bidding?
What strengths do you see?
What weaknesses do you see?
Where and how would you like to see it used?
Where do you think it should not be used?
Where do you think the savings from Dynamic bidding comes from? (money doesn't grow on trees, where is the savings coming from)
What's the Buzz on DBE? (what do you hear others saying about it)

Early Supplier Involvement Information:

What is the advantage of sourcing before the design is finalized?
How often does this advantage manifest itself in the end product?
How accurately can you predict the cost of your commodity
How do you validate (non DBE) that you are getting a good price?
What is the largest challenge with the supplier?
When do you think you should use Dynamic Bidding in the sourcing process for ESI?
Has the level of service dropped since using DBE's? (long term impacts).

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