Outsourcing Engineering Design in a Semiconductor Equipment Manufacturing Company

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Submitted to the Sloan School of Management and
the Department of Civil and Environmental Engineering
in partial fulfillment of the Requirements for the Degrees of

Master of Business Administration
And
Master of Science in Civil and Environmental Engineering

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Abstract

This thesis seeks to examine internal processes that can be developed by manufacturing firms to assist in outsourcing significant portions of the engineering design of new products. The primary focus is on reducing the risk associated with the outsourcing of engineering design and new product development. Critical factors discussed in the thesis include: selection of specific modules to be outsourced, financial implications, selection of strategic partners, structure of the co-development agreement, and the ability to integrate suppliers into a company's internal product development process. In addition, the thesis explores the roles and impact of different functional groups within the organization during the outsourcing process.

The research and analysis for this thesis were conducted at Axcelis Technologies, Inc. a partner company of the MIT Leaders for Manufacturing (LFM) program. Research methods included a literature review of best practices, a review of current manufacturing outsourcing processes, personal interviews, and observations of contract negotiations with current suppliers.

Axcelis Technologies, Inc., is a semiconductor capital equipment manufacturer located in Beverly, Massachusetts. Axcelis' key product lines include ion implanters, rapid thermal processors, and dry strip and photostabilization equipment. The products are extremely complex, while sales volumes are relatively low in an industry recognized for its volatile business cycles.

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I would be remiss not to thank my parents for their lifelong love, support, sacrifice and incredible examples. They have always encouraged me to chase my dreams and have helped in every way imaginable. Thanks mom and dad—I owe it all to you!

Most importantly, I would like to thank my wife Holly and my sons Taylor and Porter for their continual love, patience and support. You remind me daily of what true happiness is really about, and I feel so blessed to have you in my life!

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List of Acronyms

GEBN	Global Procurement and Supply Chain Electronics Benchmarking Network
NPD	New Product Development
OEM	Original Equipment Manufacturer
PAC	Product Approval Committee
PACE	Product and Cycle-time Excellence
PRTM	Pittiglio Rabin Todd & McGrath
R&D	Research and Development
RFP	Request for Proposal
RFQ	Request for Quote
SOW	Statement of Work
TPS	Technical Performance Specification

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Chapter 1: Introduction and Project Overview

1.1 Project Setting

Axcelis Technologies, Inc. is a semiconductor capital equipment manufacturer located in Beverly, Massachusetts. Axcelis' key product lines include ion implanters, rapid thermal processors, dry strip and photostabilization equipment. The products are extremely complex and are comprised of 3000 to 5000 purchased or manufactured parts. In addition, sales volumes are relatively low in an industry recognized for its volatile business cycles.

Over the past year and a half Axcelis has implemented a strategic outsourcing initiative to outsource non-core capabilities. A key objective of the outsourcing initiative is to increase production capacity during an up-cycle, while limiting the exposure during a downturn. The outsourcing initiatives to date have focused on manufacturing projects. As Axcelis begins to outsource engineering design as well as technology development, the existing tools and processes for outsourcing manufacturing do not necessarily apply. Hence, there is a strong need to develop a set of tools, processes and best practices that will guide Axcelis in partnering with suppliers to perform the engineering and design for significant portions of new product development.

1.2 Axcelis Background

Axcelis began as an operating division under the Eaton Corporation. After 20 years with Eaton, Axcelis spun off as an independent publicly owned company in 2000. Since the spin off from Eaton, Axcelis has focused on establishing its own identity as a technology leader in the semiconductor equipment manufacturing industry. Sales revenue for FY2002 was $309.7 million. Key competitors include Applied Materials, Inc. and Varian Semiconductor Equipment Associates.

Principal manufactured product portfolios consist of ion implanters, rapid thermal processors, and dry strip and photostabilization equipment, which are utilized in the semiconductor chip manufacturing process. The semiconductor industry is notoriously cyclical with radical swings in the customer demand cycle that are exacerbated by Axcelis' position in the supply chain. The value chain in the semiconductor industry is illustrated in the following figure.

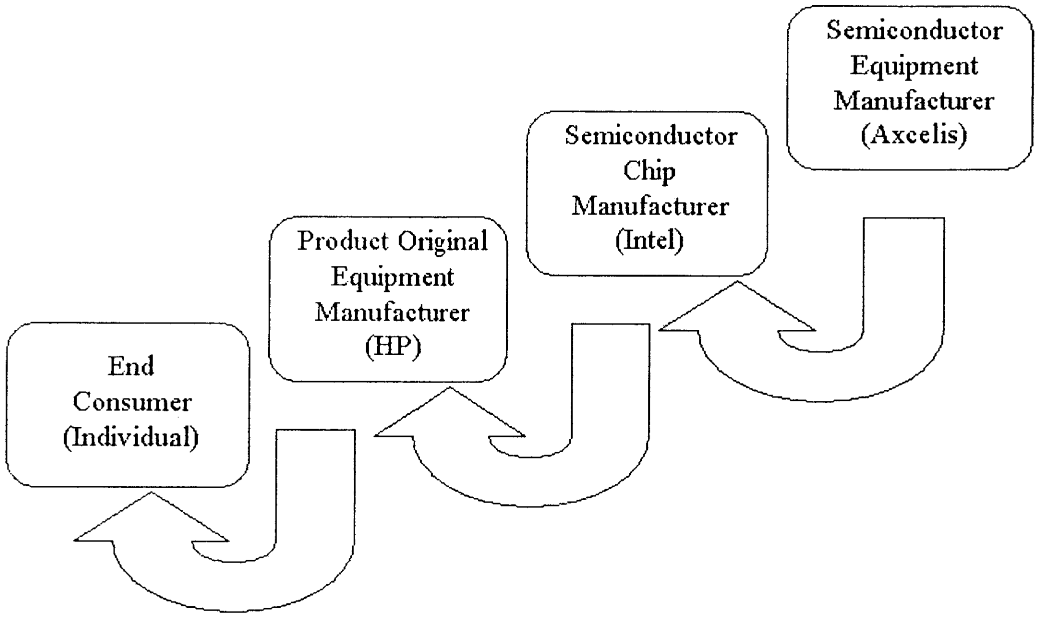

Figure 1 – Semiconductor Supply Chain

The original equipment manufacturers (OEMs), chip manufacturers, and semiconductor equipment manufacturers all experience the cyclical demand cycle. However, the demand swings are exacerbated with each successive step upstream in the value chain. The following figure illustrates the cyclical demand in the semiconductor industry from the perspective of the various participants.

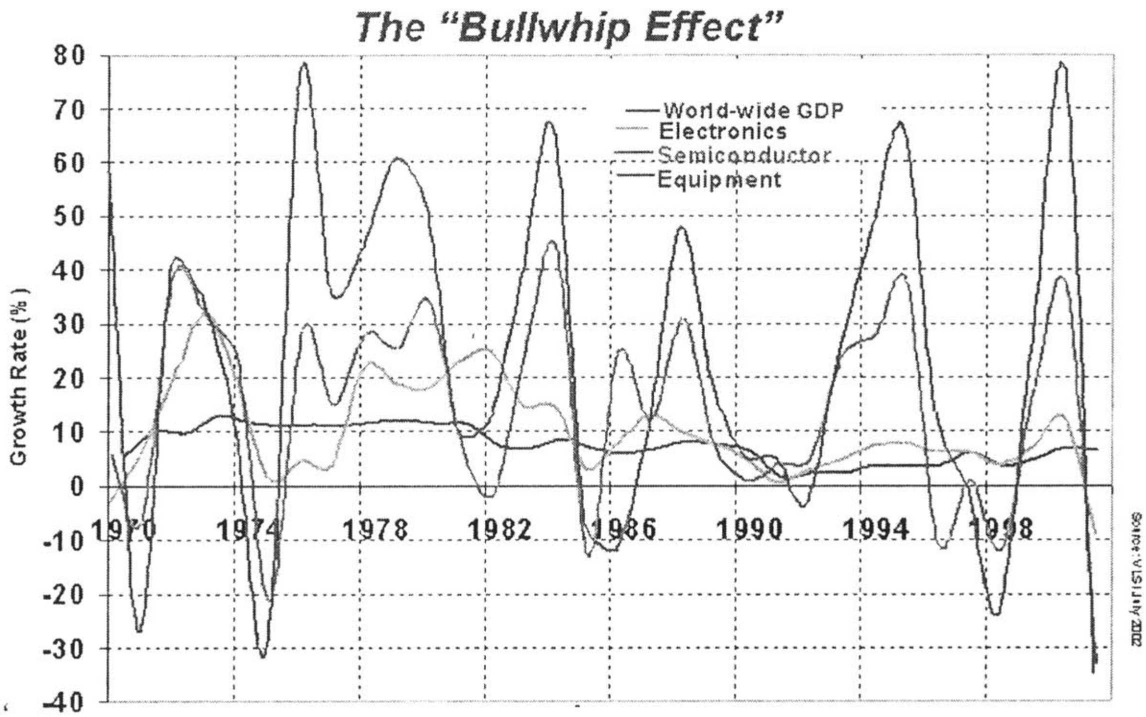

Figure 2 – Bullwhip Effect in the Semiconductor Industry [Maydan 2002]

The bullwhip effect refers to the increasing amplitude of the demand cycle of the upstream businesses. As can be seen the growth of world-wide GDP is fairly level with only minor oscillations. The electronics industry exhibits greater oscillations than the GDP. The semiconductor manufacturers, who are suppliers to the electronics industry see even a greater swing in demand. Axcelis and other semiconductor equipment manufacturers see the greatest swing in demand of the four.

To compound the problem the manufacturing process must optimize the production of a low volume, high mix product. For example, ion implanters, which are the primary product produced by Axcelis, are highly technical and complex products composed of up to six thousand parts and selling a relatively small number annually for up to six million dollars each.

1.3 Factors Influencing Decision to Outsource Manufacturing

Prior to this internship project, Axcelis implemented a large-scale sourcing initiative to outsource the manufacturing of assemblies and sub-assemblies deemed to be non-core to the business strategy. A key objective of the sourcing initiative was to dampen the negative effects to the organization that result from the cyclical demand cycle. During an upswing in demand, additional employees and manufacturing space were required to fulfill orders. In contrast, during a downswing in the demand cycle less manufacturing capacity and labor hours were needed. The shift in resource allocation always trailed the trends in demand. For example, during an upswing it took time to hire skilled employees and expand capacity leaving valuable demand unfulfilled. Similarly, during a downswing the additional manufacturing capacity represented a large fixed cost that was not easily eliminated. Cyclical demand and outsourcing both result in the loss of corporate knowledge, however in the case of outsourcing the knowledge loss is carefully managed. Only functions that are not deemed critical to the business strategy are outsourced so that knowledge loss is minimal. In contrast, during cyclical downsizing critical corporate knowledge might be lost. Downsizing of human capital is typically based on factors such as seniority, performance ratings, etc., but rarely based upon the criticality of the knowledge held by each individual.

The recently created Strategic Sourcing Group drove the strategic sourcing initiative. The Director of Materials, who reported directly to the VP of Operations, oversaw the group. Under the purview of operations, the Strategic Sourcing Group focused on outsourcing the manufacturing of non-core assemblies and sub-assemblies. Assemblies were categorized based on the following five categories, which were derived from Prof. Charlie Fine's book *Clockspeed*: Customer importance (high, medium, low), technology clockspeed (fast, medium, slow), competitive advantage (advantage, parity, disadvantage), capable suppliers (none, few, many), and product architecture (integral, modular) [Fine, p. 52, 2003].

Axcelis hoped to derive benefit from the expertise and experience of selected suppliers, as well as through an internal focus on core competencies. After conducting a strategic sourcing workshop, the Strategic Sourcing Group identified and prioritized several outsourcing projects. By the start date of my internship project, June 2002, Axcelis had began contracting out the selected outsourcing candidates. To facilitate and standardize the strategic sourcing process, a 14-Step Sourcing Process was created [Blaha 2002]. In addition, a group of tactical tools were created to assist sourcing personnel in accomplishing each step or group of steps.

1.4 Factors Influencing Decision to Outsource Engineering Design

Axcelis' goal was to outsource not only the manufacturing, but also significant portions of the engineering design of future products. This objective offered the ideal opportunity for an MIT LFM intern to help create and implement the necessary processes and tools, since outsourcing engineering design adds several new complexities to the Axcelis process. First of all, the outsourcing engineering effort will cross several organizational boundaries. Previously, all strategic sourcing efforts were handled under the operations division, which simplified the required coordination and approval processes. The Strategic Sourcing Group must now work closely with the selected engineering product design teams throughout the sourcing process. Key decisions must receive joint approval and meet the requirements of both Engineering and Operations. Furthermore, the roles and responsibilities of each division are not currently defined for each phase of the project. Secondly, there are additional risks inherent to engineering design outsourcing, which are not present in the outsourcing of manufacturing. For example, key concerns include intellectual property ownership, design liability, confidentiality and design feasibility. Several of the tactical tools created to assist the Strategic Sourcing Group through the 14-Step process are specific to manufacturing and do not address these concerns with engineering design outsourcing. Several new tactical tools were needed to reduce risk exposure and address these concerns.

1.5 Project Description

The purpose of the internship project was to create, organize and/or consolidate the necessary tools and processes required to outsource significant portions of the engineering design of new products. This extended set of tools, processes and best practices must reflect the step increase in risk and complexity associated with outsourcing design and technology development:

- Technology driven risk such as feasibility and intellectual property ownership

- Increased complexity as outsourcing design and engineering requires much closer cooperation and much more fine tuned interfaces between Axcelis and supplier organizations and products
- Complexity of defining and comparing total internal design costs versus cost of outsourcing

Organizational roles and responsibilities throughout the strategic sourcing process must be established for the Strategic Sourcing Group, engineering product design teams, and the outside suppliers.

1.6 Approach and Methodology

The current outsourcing process was analyzed to identify which additional tools and processes would be required to enable the outsourcing of major portions of the engineering design. Considerable insight was gained from personal interviews with participating individuals, as well as observations of actual contract negotiations with strategic partners. A literature review was conducted to identify best practices and lessons learned. The actual process was implemented through a cross-functional team. Two outsourcing efforts were piloted through the newly created process. The actual internship project was composed of three phases as described below.

1.6.1 Phase 1

The first phase, focused on assessing the current tools and best practices available within Axcelis to support engineering design outsourcing of key elements of future products. The assessment included:

- Interviews with key functional subject matter experts and stake holders, including but not restricted to: Specific product operations platform representatives, Operations Program Managers (OPMs), product core teams, outsourcing wheel[1] leads, purchasing managers, key subset of senior management
- Review of existing tools and processes, including: Terms and Conditions, commercial assessment template, strategic outsourcing process, and core competency assessment for future product lines
- Review of existing functional and design team organizational alignment and linkages
- Review of engineering design outsourcing best practices

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[1] Sourcing wheels are cross-functional groups, which are established to implement or execute various aspects of the sourcing process.

The outcome of the first phase was an assessment of the current gap between existing Axcelis processes, tools, and organizational alignment and those necessary to successfully implement the outsourcing of the engineering design.

1.6.2 Phase 2

The second phase focused on developing and consolidating those tools, processes and best practices that were required to close the gap identified in the first phase. The solution set included the necessary tools and processes required for:

- Evaluation of the financial payback inherent with outsourcing the engineering and design of major modules
- Preparation and release of contract request for proposals
- Appropriate structuring of a co-development agreement with the selected supplier (terms and conditions)
- Performance measurement and control of the selected design partner
- Inclusion of the supplier product development processes into Axcelis' product development process
- Joint development of timelines and risk sharing with the selected design partner
- Termination of supplier agreements
- Internal organizational linkages required to streamline activities, roles, and communication

The tools were developed in conjunction with functional subject matter experts and process owners through joint work sessions.

1.6.3 Phase 3

The third phase consisted of applying and validating the above tools, processes and best practices through a number of pilot design outsourcing efforts with a new product currently under development. Results of the piloting effort were used to modify and improve the process.

1.7 Thesis Overview

This thesis will explore methods for successfully outsourcing engineering design. The thesis is based on an MIT Leaders for Manufacturing (LFM) internship project with Axcelis Technologies. The remaining chapters of the thesis are structured as follows:

Chapter 2 explores "best practices" used by manufacturing firms to effectively outsource engineering design. The chapter focuses on the strategy, management, and processes, which pertain to engineering design outsourcing. The integral relationship between a firm's vertical integration strategy and its strategic outsourcing initiatives is investigated.

Chapter 3 reviews the actual outsourcing and new product development processes used by Axcelis prior to the start of the internship project. The 14-Step Strategic Sourcing Process, which was created for outsourcing manufacturing and assembly, is introduced and described in detail. The structured NPD process used by Axcelis, which is known as Product and Cycle-time Excellence (PACE), is explained. The major shortcomings of the current 14-Step Strategic Sourcing Process and associated tools in outsourcing engineering design are also identified and discussed.

Chapter 4 investigates the existing organizational dynamics that affect the engineering design outsourcing process. The organization is explored from three perspectives: strategic design, political, and cultural. Primary focus is on the Operations and Engineering Divisions. Insight gained from the various perspectives is used to orchestrate effective change management during the internship project. Organizational change management at Axcelis is analyzed during three critical phases: building momentum, visionary change, and refinement.

Chapter 5 explores the development and implementation of the engineering design outsourcing process. The crucial role of the cross-functional working group is explained in detail. In addition, several of the tools and processes created during the internship project are introduced. Primary focus is on the request for proposal tools and the roles and responsibilities of the various players throughout the process. Finally, the chapter reviews the process implementation steps utilized during the project.

Chapter 6 presents conclusions and recommendations for implementing an engineering design outsourcing process at a manufacturing firm such as Axcelis.

Chapter 2: Best Practices and Strategy in Outsourcing Engineering Design

2.1 Chapter Overview

The purpose of this chapter is to explore "best practices" used by manufacturing firms to effectively outsource engineering design. The chapter focuses on the strategy, management, and processes, which pertain to engineering design outsourcing. The strategy portion of this chapter explores both the primary reasons firms seek to outsource engineering design, and the integral relationship between the vertical integration strategy and strategic outsourcing. The management section reviews effective methods to integrate suppliers into a manufacturing firm's new product development process, and the organizational structure required to manage these relationships. Finally, the process section discusses the effective use of "request for proposals" in engineering design outsourcing.

2.2 Vertical Integration Strategy

Strategic sourcing decisions can alter the level of vertical integration within the firm. Thus it is essential for manufacturers to establish and proactively manage the vertical integration strategy before initiating strategic sourcing initiatives. In fact, the strategic sourcing decisions will dictate the level of vertical integration in the absence of a clearly defined strategy. The reason is simple. Strategic Sourcing decisions alter the capabilities within the firm. Over time a series of sourcing decisions will often lead to the loss of specific capabilities within the firm. It is clearly preferable for a manufacturer to actively select the level of vertical integration desired based on its long-term strategy rather than through a series of uncoordinated outsourcing efforts.

2.2.1 Macro Reasons to Vertically Integrate

Vertical Integration may or not be advisable to a manufacturer. Each firm must determine its own optimal level of vertical integration based on its unique circumstances. In an article published in the Sloan Management Review John Stuckey and David White highlighted four reasons to vertically integrate, which are as follows:

- The market is too risky and unreliable – it "fails"
- Companies in adjacent stages of the industry chain have more market power than companies in your stage
- Integration would create or exploit market power by raising barriers to entry or allowing price discrimination across customer segments
- The market is young and the company must forward integrate to develop a market, or the market is declining and independents are pulling out of adjacent stages

[Stuckey, p.71-72, 1993]

According to the authors the first reason, vertical market failure, is the most important reason. A market fails when "transactions within it are too risky and the contracts designed to overcome these risks are too costly (or impossible) to write and administer" [Stuckey, p.71-72, 1993]. The most common features of a failed vertical market are:

- A small number of buyers and sellers
- High asset specificity, durability, and intensity
- Transaction frequency

[Stuckey, p.71-72, 1993]

While each feature individually does not usually indicate a vertical market failure, these features in conjunction typically represent a failed vertical market.

Companies must evaluate their unique situations and the need to vertically integrate. If the reasons listed above are evident in their market, it might be advisable to maintain a high level of vertical integration. By outsourcing critical capabilities to suppliers, manufacturers might eventually lose the capabilities in an environment where it is advantageous to have them.

2.2.2 Core Competencies

With a clear understanding of its core competencies, a company can focus on leveraging these skills to increase its competitive advantage. The identification of core competencies is also critical to the establishment of a successful vertical integration strategy. However, in order to identify its own core competencies a company must first understand the definition of a core competency. James Quinn and Frederick Hilmer suggested that effective core competencies are:

- Skills or knowledge sets, not products or functions

- Flexible, long-term platforms – capable of adaptation or evolution
- Limited in number (not one and rarely more than five)
- Unique sources of leverage in the value chain
- Areas where the company can dominate
- Elements important to the customer in the long run
- Embedded in the organization's systems

[Quinn, p.45-47, 1994]

Companies must work to protect these competencies both upstream and downstream by creating barriers to erosion. Thus manufacturers might want to continue to perform activities which are considered "essential" but not "core" if the outsourcing of these activities diminishes the ability to protect core competencies. Without a vertical integration strategy that identifies both the core competencies and methods for safeguarding these competencies, a company might inadvertently lose their protective barriers through outsourcing.

2.2.3 Factors to Consider in Making Vertical Integration Decisions

Several macro reasons for vertically integrating are listed in Section 2.2.1. However, in order to actually apply a vertical integration strategy to each strategic outsourcing decision a company must explore the situation from several distinct angles. Sara Beckman and Don Rosenfield suggest four sets of factors, which can be used as a screen for whether or not the item should be outsourced. The four sets of factors include: strategic, market, technology and economics [Beckman, Ch.3, 2004]. An outsourcing candidate should pass each of the four screens in order to be outsourced.

<u>Strategic Factors</u>

Strategic factors consider whether or not an activity is critical to developing and/or sustaining the core competencies of the firm [Beckman, Ch.3, 2004]. If activities are deemed to be core competencies, the company should focus on maintaining these activities internally. The only exception is for capabilities that are deemed to be core yet which the company does not currently possess. Under this scenario the company should seek to develop the capabilities internally, while seeking a supplier to provide such capabilities in the interim.

The active management of the vertical integration strategy can also help to limit the loss of valuable corporate knowledge. If companies continually increase and decrease fulltime engineering staff with each market cycle, valuable knowledge can be lost. However, by maintaining a smaller core group of fulltime engineers, which does not significantly increase or decrease in size with market oscillations, companies can more easily limit the loss of critical knowledge. The outsourced engineering work is considered non-core to the companies strategy and products. Since non-core engineering functions are by definition less critical, loss of this knowledge is less risky to the outsourcing company.

Market Factors

Market factors consider three elements: market reliability, aggregation of demand and market structure [Beckman, Ch.3, 2004]. Market reliability is related to the vertical market failures discussed previously. If healthy competition exists and it improves supplier performance, then it might be advisable to outsource. However, if the supplier market for a particular capability is continually at risk of failing then it is advisable to maintain internally. If a supplier has a strong customer base for the needed service, the supplier will typically be able to provide services cheaper than the manufacturers internal cost due to economies of scale. In addition, the aggregated demand will serve to lessen variability and allow the supplier to more efficiently utilize its resources. Finally, market structure refers to the sources of power within the value chain. If manufacturers can gain power either as a buyer or supplier by vertically integrating it is often advisable to do so. In addition, if the manufacturer becomes overly dependent on a supplier it will naturally increase the supplier's power within the partnership. If this is deemed to be too risky a company should explore creating such a capability internally.

Product and Technology Factors

Firms need to look at both the product developed and the technology. If the product is highly modular, it enables manufacturers to more simply outsource portions of the design or manufacturing. However, if the product is highly integral it is much more difficult to outsource portions of the development. Similarly, a firm must decide if a particular technology is integral to the product design or whether it is a "stand alone" technology that can easily be replaced with an alternative solution [Beckman, Ch.3, 2004]. Furthermore, the company must consider whether it currently manages the technology in house. If not it must determine whether to develop the capability or partner with an outside firm.

Economic Factors

In many instances the first three factors will determine the need for vertically integrating. However, a firm should seek to understand the total costs of developing and managing an activity internally versus the cost of outsourcing. The following table summarizes the costs a firm should explore in making the outsourcing decision.

Type of Cost	Cost of Owning Activity	Cost of Outsourcing an Activity
Production or service delivery costs	Materials Labor (Direct) Overhead Production Procurement Engineering	Purchase cost includes: Labor (Direct) Materials Overhead Vendor profit
Transportation and logistics costs	Cost of moving output from site of production to site of use	Cost of moving output from vendor's location to buyer's site of use
Investment costs	Capital (equipment and space) People resources (hiring, training) System Development Inventory	
Transaction costs		Contracting costs including purchasing, sales, marketing, taxes, legal Coordination costs including engineering, forecasting, production scheduling

Table 1 – Comparison of Costs for Internal Ownership Versus Outsourcing [Beckman, Ch.3, 2004]

The goal to replace fixed cost with variable costs is common outsourcing objective, since variable cost can be more easily reduced during adverse market conditions. In outsourcing manufacturing operations companies can lower fixed costs associated with equipment, facilities, and labor. While the fixed cost reduction of equipment and facilities might not be as drastic in engineering design outsourcing efforts, the fixed labor cost of engineers might be considerable. Companies such as Axcelis, which have highly variable swings in the volume of engineering work required, can maintain a reduced staff of engineers to handle core engineering activities. When demand increases these companies can outsource the additional engineering work as required [Bragg, p.157, 1998].

2.2.4 Summary of Vertical Integration Factors

The following table summarizes when it is advisable to vertically integrate versus vertically disintegrate based on the four screening factors.

	Vertically integrate to:	Vertically disintegrate to:
Strategic Factors	• Develop and retain core and essential capabilities	• Access a core or essential capability while working on its development internally
Market Factors	• Control cost, quality, availability and features performance in unreliable markets • To shift power relationships in the industry • To reduce dependency (due to asset specificity) on suppliers	• Leverage competition among suppliers to access best-in-class performance • Aggregate demand at suppliers thus generating economies of scale and improved responsiveness to variability in demand
Product and Technology Factors	• Control integral or critical technologies • Integrate design and production under uncertain conditions	• Access current technologies not available internally • Obtain leverage available from modular product architectures
Economic Factors	• Minimize transportation and logistics costs • Minimize transaction (contracting and coordination) costs	• Access lower production or service delivery costs • Obtain economies of scale not obtainable with internal volumes • Minimize investment costs

Table 2 – Factors for and Against Vertical Integration [Beckman, Ch.3, 2004]

2.3 *Reasons to Outsource Portions of the Engineering Design*

In order for firms to remain competitive in the face of increasing global competition, firms must decrease product development time while simultaneously improving quality and functionality. Many companies have focused on concurrent engineering and process reengineering to reduce the development time. Another successful practice has been to involve suppliers earlier in the product development process. Early supplier involvement can range from simple advice and consultation to the conceptualization and design of entire systems. The following subsections explore potential benefits to outsourcing engineering design if managed effectively. However to achieve these gains suppliers must be carefully selected based on their ability to improve the technology, time to market and quality. In addition, suppliers must be strongly integrated into the development process

2.3.1 Design Flexibility and Cost of Design Changes

A key reason to select a supplier is for their expertise in a particular specialty. In order to gain from a supplier's expertise, the buyer must involve the supplier during the initial design phases. An estimated 70 to 80 percent of the product cost is established during the early phases of the product design [Laseter, p.133, 1998]. During the later stages of development the product design is much less flexible. Most design changes during the later stages of development incur significantly higher costs as seen in the following figure.

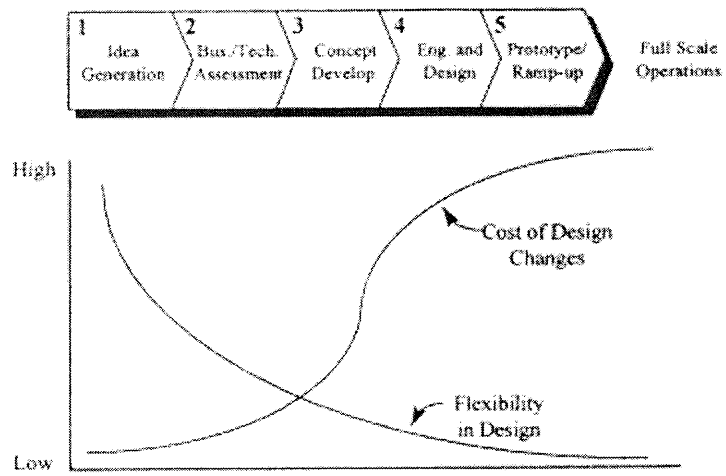

Figure 3 – Design Flexibility and Cost of Design Changes [Monczka 1997]

Most firms typically have involved suppliers during later stages, and were not able to implement supplier's suggested design improvements due to the high cost of changing the design.

The Global Procurement and Supply Chain Benchmarking Initiative at Michigan State University (MSU) has been conducting an interesting study of the strategies and best practices for integrating suppliers into the new product development process. A survey was sent out to numerous companies participating in MSU's Global Procurement and Supply Chain Electronics Benchmarking Network (GEBN) with 124 companies responding. The survey found that those companies which integrated suppliers in the development process earlier reported significant improvements in material cost, material quality, development time, development cost and functionality/features/technology. The median performance improvements of projects involving supplier integration over similar projects without supplier integration are shown in the following table.

	Stage of First Integration of Supplier**		
Performance Dimension:	**Early** (Stage 1 or 2)*	**Middle** (Stage 3)*	**Late** (Stage 4 or 5)*
Purchased Material Cost	20 %	15 %	10 %
Purchased Material Quality	20 %	15 %	15 %
Development Time	20 %	20 %	10 %
Development Cost	20 %	10 %	10 %
Functionality/Features/Technology	20 %	10 %	10 %
Product Manufacturing Cost	10 %	12 %	10 %
*Stages refer to the stages as shown in Figure 3 **Compared to similar projects in which a supplier was not integrated			

Table 3 – Median Performance Improvement by Stage of First Integration of Supplier [Monczka 1997]

It is interesting to note that even late stage integration of suppliers into the development process achieved performance improvements over projects with no supplier integration.

2.3.2 Improved Time to Market and Product Quality

Two of the most notable benefits of successful early supplier integration are a decrease in the time to market and improvements in product quality from the customer's perspective. Time to market is typically improved since the buyer can focus on its core competencies or strengths in the design, while the suppliers focus on the outsourced portions that relate to their own individual core competencies. In house engineers were often overloaded with tasks, however the addition of suppliers helped by increasing the number of actual engineers working on the project in a concurrent fashion. In addition, suppliers were typically selected for their superior technology or experience with respect to the outsourced item and should be able to develop it faster than the buyer could in house.

Many of the same factors that contribute to a reduction in time to market also serve to improve the product quality from the customer's perspective. The suppliers are able to positively influence the design at early stages while the design is still flexible.

Furthermore, the suppliers' superior technology or experience with the outsourced item will lead to better product. In a separate survey from that described in Section 2.3.1, the GEBN compiled data on 60 companies to determine the effects of supplier integration on the product's material cost, quality and development cycle time. Each company was asked to include data on both their most successful and least successful supplier integration efforts. The following table shows the median percent improvement from supplier integration for both the most successful and least successful cases compared to a case without supplier integration.

Parameter	Most Successful Cases	Least Successful Cases
Cost**	15.0 %	(5.0 %)
Quality***	40.0 %	(7.5 %)
Development Cycle Time	25.0 %	(30.0 %)
*Figures in parentheses indicate a *deterioration* on the performance dimension **Relative to historical costs for this item or similar item ***Relative to historical quality for this item or similar item		

Table 4 – Median Percent Improvement Resulting From Supplier Integration [Ragatz 1996]

It is interesting to note that the upside of cost and quality on the most successful cases was much higher than the down side associated with the least successful cases. However the downside in development cycle time was greater than the upside for the most successful case. While the preceding table shows the extreme cases it is not obvious whether or not the companies valued the supplier integration. However, the survey also asked the respondents to highlight their intent to integrate suppliers into the product development process in the future. The following figure represents the compiled response from the companies.

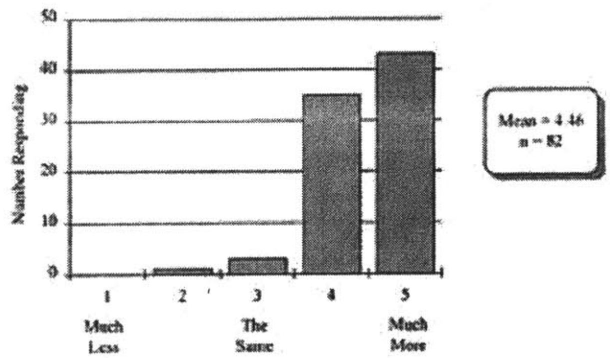

Figure 4 – Extent to Which Companies Will Integrate Suppliers into NPD in the Future [Ragatz 1996]

The majority of respondents obviously intend to integrate suppliers into the new product development process much more than in the past. This desire reflects the satisfaction companies have experienced from early supplier integration.

2.4 Supplier Management and Integration

To achieve any of the desired performance benefits mentioned previously in this chapter, the supplier must be effectively integrated into the company's product development team and managed effectively throughout the relationship. A company must clearly identify the role and functions they expect an integrated supplier to perform, since there are various levels of integration and supplier participation. To obtain success over the long term a company must work to align the objectives and incentives of the supplier with its own.

2.4.1 Levels of Supplier Integration

Breaking the levels of supplier integration into specific categories can assist in understanding the management effort required to manage the relationship. The following figure illustrates the spectrum of potential supplier integration in the product development process.

None	"White Box"	"Gray Box"	"Black Box"
Supplier "makes to print"	Buyer "consults" with supplier on buyer's design	Joint development activity between buyer and supplier	Design is primarily supplier driven based on buyer's performance specifications
No supplier involvement in design	Informal supplier integration	Formalized supplier integration	Formalized supplier integration

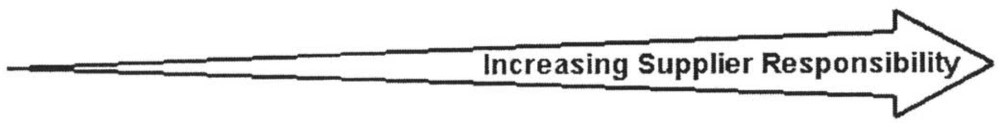

Figure 5 – Spectrum of Supplier Integration in Product Development [Monczka, p. 106, 2000]

Both the "Black Box" and "Gray Box" classifications require a formalized contract or partnering agreement in addition to a standard non-disclosure agreement. The "Gray Box" typically requires the highest level of day-to-day management of the supplier since the decisions and tasks are accomplished jointly. The "Black Box" requires more up front planning with frequent interaction over the life of the project. However, the supplier is given more autonomy to design, as long as the buyer's performance specifications are met. The "White Box" and "None" classifications require a non-disclosure agreement, but do not require a formal contract. The "White Box" suppliers are usually willing to participate in informal discussions of the design since it usually implies the buyer will be utilizing the supplier's components or products in the design. While the optimal level of supplier integration is case specific, early supplier involvement in the product development will almost always lead to improved performance. The key lesson to be learned is that the greater the responsibility given to the supplier, the greater the need to integrate the supplier earlier in the process.

2.4.2 Supplier Integration Execution Process

The decision to outsource portions of new product development is significant, and should be undertaken carefully. Outsourcing projects and respective suppliers must be selectively chosen based on the business strategy and the ability to successfully integrate the supplier into the new product development process. The following figure illustrates a successful framework for integrating suppliers into the development process.

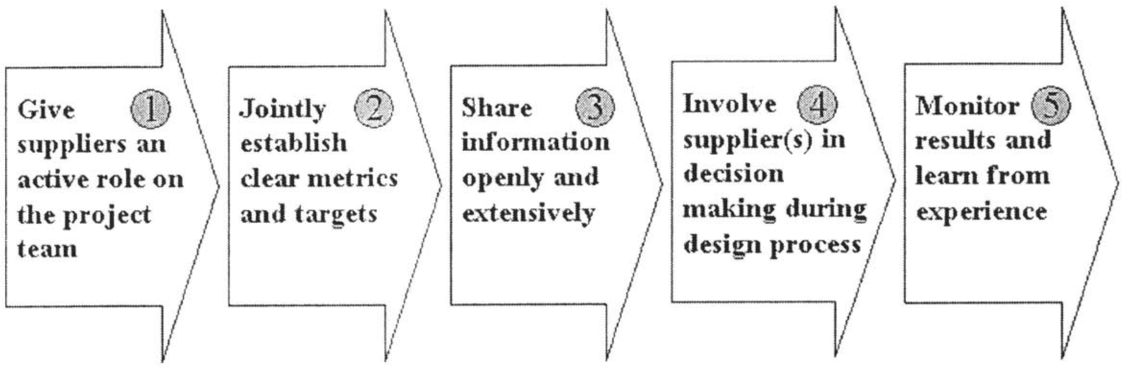

Figure 6 – Supplier Integration Execution Process [Monczka, p. 4, 2000]

Each of the five points shown in the preceding figure are further explored below.

<u>Give Supplier an Active Role</u>

To effectively harness the experience and expertise of the supplier, they must be actively involved. While the supplier does not need to be present at every meeting, they must be apprised of and participate in decisions that are relative to their involvement. The greater the complexity of the development project, the greater the level of supplier participation [Monczka, p. 22, 2000]. At times it might be advisable to co-locate the supplier with the new product development team. However, advanced communication and technology systems make it much easier to include the supplier in critical meetings and discussions from off-site locations.

<u>Establish Clear Metrics and Targets</u>

By jointly establishing metrics both companies are able to establish aggressive yet reasonable goals. In addition, the joint process assists in gaining supplier buy in. Clearly defined targets, such as design to cost, give both companies a common direction and serve as the basis for:

- Evaluating progress

- Making design tradeoffs
- Resolving conflicts

[Monczka, p.23, 2000]

Clear metrics and targets are extremely important for companies with little experience working together.

Share Information Openly and Extensively

In order to share information openly and extensively, it is critical to ensure design and engineering personnel from both companies communicate directly. To be successful, companies must establish guidelines for direct communication, and must establish mechanisms to keep the project team and other relevant functions informed. In addition, the sharing of long-term technology roadmaps can be helpful in achieving future technology alignment. However, in order to provide open access to information companies must agree to nondisclosure or confidentiality agreements.

Involve Supplier in Decision Making Process

Suppliers should also be included in the decision making process. The goal of supplier integration is to make the supplier an active member of the development team. Since the supplier is selected based on its particular expertise, the buyer should exploit this asset and include the supplier in decisions relating to the supplier's expertise. Supplier participation typically leads to better decisions by the project team, and also enables faster problem resolution during the design phase. Involvement can be facilitated through face-to-face meetings, point-to-point inter-firm communications, temporary co-location, teleconferences, or even email [Monczka, p.25, 2000].

Monitor Results and Learn from Experience

Regular evaluation and continuous improvement should be the norm in the company if long-term gain is desired from supplier relationships. The key lessons learned from each evaluation should be communicated throughout the firm to assist in continuous improvement. Without a system to perform periodic reviews and to communicate findings throughout the organization, systematic improvement will be slowed or stymied. Supplier input should be sought and included as well.

2.4.3 Aligning Objectives and Incentives

Early supplier involvement in the new product development process can be advantageous as previously discussed. However, the supplier will only be committed to a long-term relationship if they feel they will benefit in the end. Thus successful outsourcing of portions of the engineering design must create a win-win scenario for both the manufacturer and supplier.

An interesting study by Seungwha Chung and Gyeong Kim looked at how supplier involvement in the manufacturer's new product development process affected the supplier's innovation, product quality and financial performance [Chung 2002]. The study looked at 128 suppliers in the Korean automobile and electronics industries. The study first looked at factors that influenced innovation on the part of the supplier. Early supplier involvement benefited the suppliers' level of innovation in several ways. First, the suppliers' direct and frequent communication with the manufacturer provided new insight into what the manufacturer really needed and how the suppliers products were really being used and integrated into the system. This additional knowledge provided suppliers with ideas for improvements, which led to product innovation throughout the suppliers product line. In addition, manufacturers often sign long-term agreements committing to buy from a supplier if they continue to perform well and meet the manufacturer's expectations. This long-term commitment increases the suppliers' willingness to invest heavily in R&D on new products. Since the long-term agreements are based on supplier performance, the supplier feels an extra push to achieve superior innovation so as not to lose out to a competitor. The following figure from the study shows the innovation improvement gained by suppliers based on the level of supplier involvement in the manufacturers' new product development process.

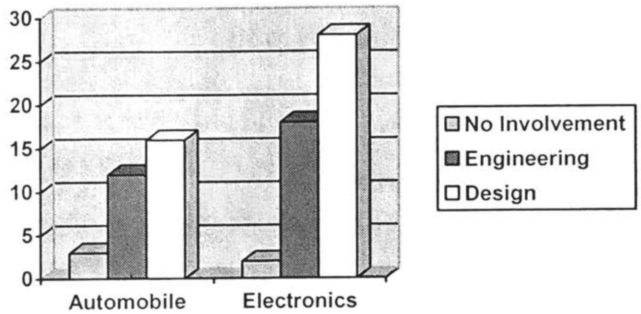

Figure 7 – Comparative Patents by Level of Supplier Involvement [Chung 2002]

The second factor explored in the Chung-Kim study was the affect on quality. By combining their complementary expertise throughout the development process, product quality is expected to be better in terms of functional performance, reliability, and design [Chung 2002]. Furthermore, the partnering relationships allow them to explore quality issues throughout the process. The final factor explored was financial performance. Companies can benefit financially in several ways. One critical area is cost savings. By working closely with the manufacturer the supplier can eliminate duplicated effort, and can optimize around the manufacturer's development process. In addition, the close partnering relationship will allow both the manufacturer and supplier to respond quicker to changing market demands, which can ultimately lead to higher sales volume and revenue. The following chart compares financial performance by level of supplier involvement in new product development.

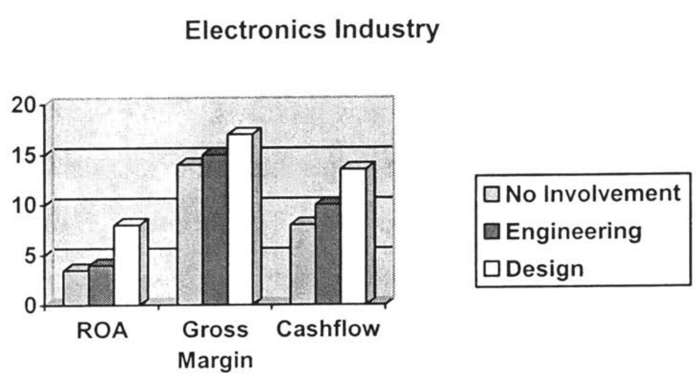

Figure 8 – Comparative Financial Performance by Level of Supplier Involvement [Chung 2002]

While each relationship is unique, the incentives and objectives should be aligned such that both partners experience a win-win situation. Improved levels of innovation, quality and financial performance by the supplier will benefit the manufacturer. In addition, the short-term gains to the manufacturer from forced supplier price reductions must be weighed against the long-term customer benefits achieved through a trusting partnership.

2.4.4 Key Barriers to Supplier Integration

The rationale for integrating a supplier into the new product development process is clear and straightforward. Even the previously recommended approaches to integrating suppliers might seem like common sense. In reality, there are numerous roadblocks or barriers to successful supplier integration that arise in practice. Typical barriers range from strategic issues such as cultural alignment, trust and business processes to operational issues such as communication problems, misalignment of objectives and inadequate definition of the roles and responsibilities.

Participants in the GEBN survey, discussed in Section 2.3.1, perceived the following items to be the greatest barrier to effective supplier integration in their respective firms:

- Unwillingness of buying company technical staff to relinquish design or technology development responsibilities (the "not invented here" syndrome)
- Suppliers and buyers concern over protecting proprietary cost information
- The time required to identify and integrate a supplier
- Buying company concern over protecting proprietary technology
- The lack of processes for integrating suppliers

[Monczka, p.9, 2000]

Research from the GEBN survey suggests companies that have been successful at supplier integration applied effective integration practices at three different levels within the company: policy level, strategic planning level and execution level. Without a systematic top to bottom approach to integrating suppliers into the new product development process a successful engineering design outsourcing effort is unlikely.

2.5 Management Structure

Outsourcing significant portions of engineering design to a supplier requires a strong partnering relationship. Since activities related to the partnering relationship cross numerous functional areas within the manufacturing firm, the partnership must be managed through a structure that can provide internal coordination, eliminate both accountability and intervention problems, and improve knowledge management efforts [Dyer, p.39-40, 2001]. By establishing a dedicated group, which is responsible for managing the strategic sourcing efforts, a firm can more effectively manage the engineering design outsourcing effort. The group must be at a high enough level within the organization to have support and visibility across functional lines. The group is given responsibility for managing the strategic partners and for the success of the associated outsourcing efforts.

One reason that partnerships typically fail is the buyers inability to effectively draw on internal resources to support the outsourcing effort. For example, if the partnering effort is initiated through the Operations division it is often difficult to generate the necessary support from the Engineering division unless it is a very high profile project. By creating a high-level strategic sourcing group to manage partnering relationships, they can more effectively utilize the necessary resources throughout the company. The sourcing group will have an organizational legitimacy to reach across functional boundaries, and over time will develop a strong network of contacts throughout the organization [Dyer, p.41,2001]. In addition to coordination, the group should also be accountable for the performance of the partnership. The sourcing group will lead the integration, establish performance metrics and resolve disputes that may arise between the two companies. Since the group is directly responsible for the success of the partnership, they will take an active role throughout the process. By centralizing the management of partnerships, the manufacturers can improve knowledge management. The sourcing group is responsible for creating tools and processes that can be used throughout the phases of the strategic sourcing process. For example, tools or processes can be developed to select outsourcing candidates, to select potential suppliers, to create and negotiate contracts, and to integrate and manage the selected supplier throughout the partner relationship.

2.6 Request for Proposals (RFP)

Much of the success or failure of an outsourcing effort can be determined by the quality and thoroughness of both the RFP and the Partnering Agreement contract. The RFP package as used by Axcelis incorporates a statement of work (SOW), a technical performance specification (TPS), a draft of the partnering agreement contract, a technical data package and guidelines for completing and submitting the suppliers' proposals. At a conceptual level the RFP is a tool used by businesses to solicit competitive bids by potential suppliers for specific goods or services. Suppliers will submit proposals, which include their proposed solutions, price, schedule, etc. Manufacturers then can select the proposal that best fits their business needs. RFPs are typically used when:

- Multiple solutions are available that will fit the need
- Multiple suppliers can provide the same solution
- Buyers seek to determine the " best value" of suppliers' solutions
- Products for the project cannot be clearly specified
- The project requires different skills, expertise, and technical capabilities from suppliers
- The problem requires that suppliers combine and subcontract products and services
- Lowest price is not the determining criterion for award
- Final pricing is negotiated with the supplier

[Porter-Roth, p.1-2, 2001]

RFPs can be advertised openly or sent only to a selected group of potential suppliers.

A key benefit to the manufacturer is the information gained from defining the business needs and requirements prior to releasing the RFP. In order to complete an RFP the manufacture must identify the business needs and translate them into measurable requirements. Furthermore, the manufacturer must determine the level of supplier integration desired. A successful RFP will enable the manufacturer to:

- Formally recognize a deficiency or need in current operations that could be resolved through the purchase of equipment or services
- Develop and implement a plan for understanding the problem
- Identify appropriate potential suppliers and solutions
- Gain visibility for internal acceptance of the identified need and potential solutions
- Establish the project budget

- Develop a project schedule
- Organize project personnel
- Evolve real requirements and ensure that they are clearly stated and measurable
- Develop rigorous evaluation criteria thus ensuring an objective evaluation

[Porter-Roth, p.17, 2001]

As can be seen by the preceding list, significant up front planning and strong leadership support are required for successful RFP development. The requirements generated during this upfront planning process can be incorporated into the SOW, TPS, and partnering agreement contract.

2.6.1 Statement of Work (SOW)

The SOW should define what work is required to be done in specific quantitative based terms. A clearly defined SOW assists suppliers in both proposal preparation and contract fulfillment. The relationship between the SOW and the technical performance specification can often be confusing. The SOW defines all work performance requirements for the supplier. The specification contains the qualitative and quantitative requirements for the product. The SOW often references the technical performance specification in describing work expectations for the supplier. A well-written SOW has the following attributes:

- The supplier should be able to estimate the project cost, manpower, level of expertise and other resources needed to accomplish the task
- States the specific duties in such a way that the contractor knows what is required and can complete all tasks to the manufacturers satisfaction
- Written so specifically that there is no question of whether the contractor is obligated to perform specific tasks
- Separates general information from direction so that background information and suggested procedures are clearly distinguishable from contractor responsibilities
- Avoids directing how tasks are to be performed and states only what results are required

[MIL-HDBK-245D 1996]

The SOW is included as an attachment to the partnering agreement contract and becomes legally binding. After the contract has been awarded, the SOW serves as the standard for measuring the supplier's performance. The SOW can be amended after contract award, but this may require modifications to the contract.

2.6.2 Technical Performance Specification (TPS)

Ideally the TPS should tell the supplier what is required, but should not tell the supplier "how to do it." A technical performance specification has two key purposes. First of all, a well-written specification should communicate the functional requirements of the product, the environment in which it must operate, and the interface and interchangeability requirements [SD-15 1995]. The second purpose of the specification is to identify the methods and procedures that will be used to verify the product meets the requirements contained in the specification.

Specifications can be categorized in one of three categories. Rajesh Nellore defined each of the three categories as follows:

- Qualitative Specifications – These specifications are essentially qualitative in terms of content. These specifications are developed within the company and are used for internal projects within the company.
- Mix Specifications – These specifications contain a well-balanced mix of qualitative and quantitative data. They can be initially generated by either the manufacturer or the supplier and are then co-developed by the other party.
- Quantitative Specifications – These specifications are essentially quantitative in terms of content. These specifications are developed by the manufacturer, while the proposed activity is completed by the supplier.

[Nellore, p.105-106, 2001]

The following table helps to determine the type of specification used, and the level of supplier integration desired based on both the project's degree of strategic vulnerability and its potential for a competitive edge. Note that all of the examples used are based on projects within the automotive industry.

Potential for Competitive Edge			HIGH *Essentially Qualitative Specification*	MEDIUM *Mix [qualitative and quantitative] Specification*	LOW *Purely Quantitative Specification*
			Degree of Strategic Vulnerability		
HIGH		• Originator of Specification	Manufacturer	Joint Development	OEM generates detailed specification
HIGH		• Contract Relationship	N/A	Joint Development • Manufacturer maintains ownership	Long-term contracts
HIGH		• Examples	Styling	Engines	Brackets
MEDIUM		• Originator of Specification	Supplier generates draft which is updated by manufacturer	Manufacturer generates draft which is updated by supplier	OEM generates detailed specification
MEDIUM		• Contract Relationship	Joint Development • Manufacturer maintains ownership	Joint Development • Supplier on retainer contract	Short-term contracts or contract order
MEDIUM		• Examples	Styling	Chassis	Interior trims
LOW		• Originator of Specification	Supplier	Supplier generates draft which is updated by manufacturer	Supplier
LOW		• Contract Relationship	Joint Development	Long-term contcts or retainers	Short-term contracts or contract order
LOW		• Examples	Audio-system validation	Glass mirrors	Hand held tools

Table 5 – Procurement Matrix Complemented by contract relationships [Nellore, p.113, 2001]

Obviously there is not a "one size fits all" scenario when it comes to outsourcing. However, the following guidelines typically apply: Qualitative specifications are insourced, quantitative specifications are outsourced without co-development, and mixed specifications are subject to co-development [Nellore, p.106, 2001].

2.6.3 Partnering Agreement Contract

Contracts can assist in assuring the supplier meets the requirements in the technical performance specification. The SOW is in essence a part of the contract. A contract has been described as:

> A framework which almost never accurately indicates real working relations, but which affords a rough indication around which such relations vary, an occasional guide in cases of doubt and a norm of ultimate appeal when the relations cease in fact to work.
> [Nellore, p.133, 2001]

Both the TPS and the SOW are bound to change during the realization of the project, and change means risk to both the supplier and the manufacturer [Nellore, p.151, 2001]. The contract can help to reduce the risks of exposure to either party. A supplier cannot be expected to enter into a long-term relationship without some expectation for gain. The contract can help to ensure both partners share in the risks as well as the gains. Common categories in a partnering agreement contract for an engineering design outsourcing effort include: Description of design services, contract price, payment, schedule, design validation, confidentiality, design ownership, termination clauses and methods for contract modifications. A contract must be specific to each contractor and each contract. In addition to project specific contracts, long-term contracts can be created, which guarantee future work over a defined period of time.

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Chapter 3: Description of Existing Strategic Sourcing and NPD Processes

3.1 Chapter Overview

The previous chapter explored the "best practices" and strategies for outsourcing engineering design, as well as the effective methods a manufacturing firm could use to effectively integrate a supplier into the firm's new product development (NPD) process. While the themes discussed in Chapter 2 are applicable to Axcelis, they should apply to any manufacturing firm seeking to integrate suppliers into the NPD process.

Chapter 3 reviews the actual outsourcing and NPD processes used by Axcelis prior to the start of the internship project. The 14-Step Strategic Sourcing Process, which was created for outsourcing manufacturing and assembly, is introduced and described in detail. The role of the steering committee, sourcing wheels, phase gates and contract administrators in managing the 14-Step Strategic Sourcing Process is also highlighted. The structured NPD process used by Axcelis, which is known as Product and Cycle-time Excellence (PACE), is explained. Finally, the major shortcomings of the current 14-Step Strategic Sourcing Process and associated tools in outsourcing engineering design are identified and discussed.

3.2 *The 14-Step Strategic Sourcing Process*

Prior to this research effort Axcelis had established a fairly robust strategic sourcing process to outsource non-core manufacturing processes. The sourcing process was divided into 14 steps, which encompassed the entire process from conceptualization through contract deliverables.

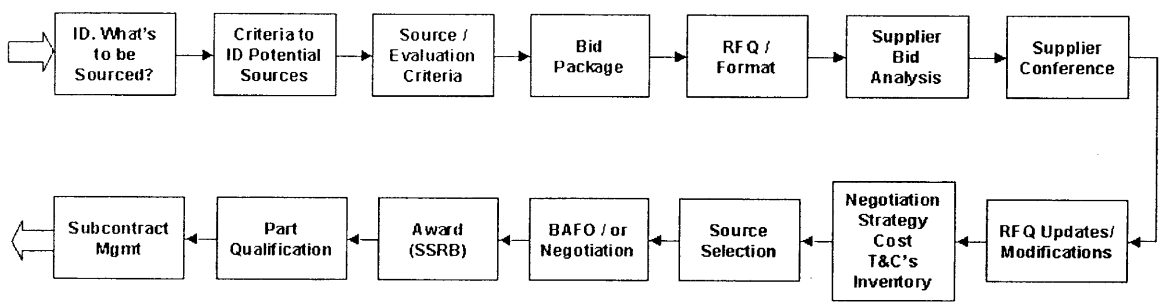

Figure 9 – Axcelis 14-Step Strategic Sourcing Process

3.2.1 Define the Objective for Each Sourcing Step

Step #1 – Identify what is to be outsourced

The primary objective of this step is threefold. First, to identify items which are considered non-core competencies and can therefore be outsourced without compromising Axcelis' key competitive advantages. Second to prioritize or select which of the identified outsourcing candidates will actually be outsourced based on modularity of design, return on investment, or time to market considerations. Finally, once the items are selected and prioritized a plan must be developed for each item to identify the actions required to source that particular item. This requires a clear understanding of the type of supplier relationship desired, the expected timeframe to complete the project, and the internal resources that will be required to complete the project. This step is the most critical step in the entire process. If inappropriate items are selected precious time and resources will be lost.

Step #2 – Identify potential sources

The desired output of this step is a list of potential suppliers who are capable of producing the selected item to be outsourced. Ideally the list of potential suppliers is chosen from a database of previously qualified suppliers who have passed a thorough commercial assessment by Axcelis. However, if there are no qualified suppliers or too few to hold a competitive source selection process then additional suppliers are sought. Potential suppliers are located through various means including lists of previous Axcelis suppliers, referrals from strategic partners or even published industry lists. If no potential suppliers are found for a particular item then the decision to outsource the item is revisited and most likely overturned.

Step #3 – Source evaluation criteria

The required capabilities of a supplier for a particular outsourcing effort should be clearly identified during the upfront planning conducted in Step #1. The capabilities of each potential supplier generated in Step #2 are evaluated and compared against the requirements established by Axcelis. While a particular supplier's full capabilities might not be known initially, they should be investigated and assessed during this step. Evaluation of suppliers is completed based upon prior knowledge, a comprehensive pre-assessment survey completed by the supplier, or ideally by an on-site commercial assessment at the suppliers' facilities by Axcelis sourcing personnel. Suppliers that do not meet the pre-established criteria are eliminated. Only suppliers fully capable of completing the outsourced effort persist in the process.

Step #4 – Preparation of bid package

The bid package includes a detailed description of the item being outsourced, performance specifications, quality requirements, master schedule, expected delivery dates, as well as any other special requirements. In addition, the package contains a detailed description of what is expected in the suppliers bid so that Axcelis can perform a side-by-side comparison of each supplier's bid. It is important that the bid package is detailed and comprehensive so that the supplier has a complete understanding of what is expected throughout the course of the contract before submitting a bid.

Step #5 – Request for supplier quote submission

Once the bid package is complete Axcelis releases a "Request for Quote" (RFQ) to all eligible suppliers from Step #3. The RFQ includes the completed bid package and specifies the deadline by which a supplier must submit a quote. Most importantly the RFQ must be released with sufficient time to complete contract negotiations by the required deadline.

Step #6 – Supplier bid analysis

All eligible quotes are entered on a spreadsheet, which highlights all of the required inputs. This facilitates a side-by-side comparison of each supplier's bid. The primary intent is to ensure that the suppliers' bids are complete and that all requested information has been provided. However, with such a complex product it is also necessary to verify that the supplier fully understood the technical requirements. The technical solutions proposed in the submitted bids are closely reviewed for feasibility. Only the most competitive suppliers will continue in the process beyond this step.

Step #7 – Supplier conference

The purpose of this step is to ensure both the supplier and Axcelis have a complete and accurate understanding of both the RFQ and the submitted bid. The supplier has the opportunity to further explore technical requirements, which may have been ambiguous. Axcelis will also have the chance to clarify specific aspects of the supplier's bid such as cost, schedule, warranties, design proposals, etc. The conference provides a clear channel for communication and allows Axcelis to gauge whether or not the supplier will be a good fit in terms of both the culture and the business processes. In addition, the conference provides Axcelis the opportunity to discuss any changes to the RFQ. While this step can be extremely beneficial to the process it is rarely completed in practice. In reality competent suppliers generally seek to resolve any questions or concerns prior to submitting bid proposals. Likewise, Axcelis typically resolves questions with respect to the bid during the initial phases of the final negotiations.

Step #8 – Request for Quote (RFQ) updates

The supplier is allowed to update its bid in this step if the RFQ is modified to allow for changes to the product design, schedule, testing or cost requirements. Ideally any modifications to the RFQ would be clearly expressed during Step #7 negating the need for any additional supplier conferences. In reality, changes to the RFQ typically occur immediately prior to final negotiations and the supplier incorporates the final bid into the negotiations process. Additional suppliers may be eliminated at this step if their updated bids are not competitive.

Step #9 – Initial negotiation process

In this step Axcelis begins negotiations with all competitive suppliers that have not been eliminated previously. The objective is to seek the best offer both technically and financially without compromising the strategic relationship with the suppliers. This phase of negotiation is used to identify and resolve specific concerns with each supplier's bid. However, care must be taken to not harm the relationship with a supplier by seeking unreasonable demands or by playing one supplier against another. Negotiations continue with each of the suppliers until Axcelis has sufficient data to select a final supplier.

Step #10 – Source selection

In this step, Axcelis will select the winning supplier. The selection is based on the final bid from each supplier. Evaluation criteria were established in Step #3 with a weighting for the importance of each factor. For example, on complex and technically challenging projects the technical capability or proposed design solution might be more important than the cost. Qualitative factors such as trust and the potential for a long-term relationship must also be considered. In most of the strategic outsourcing efforts done to date, the final selections have been quite intuitive with the winning supplier being clearly evident in the early phases of Step #9. Once the final selection has been made the final offer can be negotiated.

Step #11 – Best and final offer

The purpose of this step is to reach a final agreement with the selected supplier. Typically, Axcelis will be more willing to compromise in this step of the negotiations on issues that are of high importance to the supplier in the interest of maintaining a mutually beneficial relationship. Any lingering concerns or differences of opinion should be resolved at this stage. At the conclusion of this step, the initial partnering agreement and statement of work which were released with the RFQ are revised to reflect the agreed upon changes.

Step #12 – Award

The winning supplier is sent the modified contract. Upon signing the contract the supplier is officially awarded the outsourced contract. The supplier may or may not be allowed to announce the contract based on the terms of the partnering agreement. This step also signals the transition of the supplier from an outsourcing candidate to an actual partner. Official arrangements can then be made to begin transitioning workload, technical data, equipment, etc.

Step #13 – Part qualification

All contractual deliverables from the supplier to Axcelis must be approved prior to acceptance. The deliverables are reviewed for compliance with required technical specifications such as performance, physical characteristics, quality, etc. If the deliverable does not meet the contractual specifications, the supplier is notified and has a predetermined period of time to make the appropriate corrections. Once approved Axcelis has officially accepted the deliverable and is responsible for compensating the supplier. In addition, the accepted deliverable must be integrated back into the Axcelis product development process.

Step #14 – Subcontract management

The supplier partnership is managed from contract award through completion. In order to maximize the benefits of a partnering relationship the supplier must be integrated into Axcelis' product development and manufacturing processes. Integration includes frequent communication, joint planning, data sharing and joint decision-making. In addition, specific requirements of the partnering agreement need to be managed such as performance reviews, acceptance of deliverables, etc. While the objective of this step is obvious, it is often the most difficult step to complete successfully.

3.2.2 Tools Associated with the 14-Step Process

Specific tools were developed to assist strategic sourcing personnel in accomplishing the required tasks for each step or group of steps. The 14-Step Process is posted on an internal website which is accessible to all Axcelis employees. The website graphically displays each step and the associated list of tools. Each tool listed is hyperlinked to the most recent electronic version of the tool. In practice several of the steps are linked together so that there are nine distinct stages. The following table links the nine stages with the associated steps and tools.

Stages		Relating Steps	Associated Tools
Stage 1	1	Identify what is to be sourced	Strategic sourcing process Strategic sourcing workshop Commonality assessment
Stage 2	2	Criteria to identify potential sources	Supplier capability matrix Industry lists
Stage 3	3	Source evaluation criteria	Pre-assessment survey Assessment agenda Commercial assessment
Stage 4	4 5	Preparation of bid package Request for quote submission	Partnering agreement Statement of Work Confidentiality agreement RFQ guidelines RFQ package checklist
Stage 5	6	Supplier bid analysis	Bid analysis checklist Total cost model
Stage 6	7 8	Supplier conference Request for quote updates	N/A
Stage 7	9 10 11 12	Initial negotiation process Source selection Best and final offer Award	Negotiation strategy checklist Signature authority checklist Contract summary sheet
Stage 8	13	Part qualification	Part approval procedure
Stage 9	14	Subcontract management	Contract file checklist
General	N/A	N/A	Sourcing procedure Failure Mode Analysis (FMEA) Transition Plan

Table 6 – 14 Sourcing Steps Linked to Specific Stages and Tools

3.3 Unique Features of the 14-Step Strategic Sourcing Process

The 14-Step Strategic Sourcing Process is meant to be generic at the highest levels. The process is administered through the Strategic Sourcing Group, which falls under the Director of Materials. The process is managed through four key elements: steering committee, sourcing wheels, phase gates, and subcontract administrators.

3.3.1 Generalized Process

The 14-Step Strategic Sourcing Process should apply to outsourced manufacturing, engineering design and commercial services. However, the tools created to facilitate each step are often category specific and may not be usable or applicable for a distinct type of outsourcing effort. For example, the statement of work template that had been created to assist in outsourcing manufacturing is not usable for outsourcing engineering design. The template was written specifically for manufacturing with detailed descriptions of the manufacturing process. An engineering specific must be created to meet the demands of engineering design outsourcing. Therefore, while the overall process is applicable for all cases the specific tools, which are category specific, must be clearly labeled and identified.

3.3.2 Steering Committee

The steering committee is a senior level cross-functional group that is responsible for overseeing the strategic sourcing process. Members of the committee include the Directors of Materials, Engineering, Aftermarket Services and Lean Enterprises. In addition, executive champions such as the VP of Operations often attend steering committee meetings. The primary role of the group is to ensure that all strategic sourcing efforts are in line with Axcelis' corporate strategy. The committee establishes cross-functional sourcing wheels as required, approves each outsourcing effort during tollgate reviews, and controls any changes to the sourcing process. The committee attends bi-weekly project reviews of all outsourced manufacturing projects. Phase gates are typically held in conjunction with bi-weekly project review meetings as required.

3.3.3 Sourcing Wheels

Sourcing wheels are cross-functional groups, which are established to implement or execute various aspects of the sourcing process. For example, the first sourcing wheel was created to define the initial scope of the outsourcing process, and to determine both the level and extent of the operational support required to outsource. Once the process was established sourcing wheels were created to execute the process. Originally, three wheels were formed to direct outsourcing efforts on each of the three major segments of an ion-implanter: beam line, end station, and general systems. An example, of one of these sourcing wheels with its various participants is portrayed in the following figure.

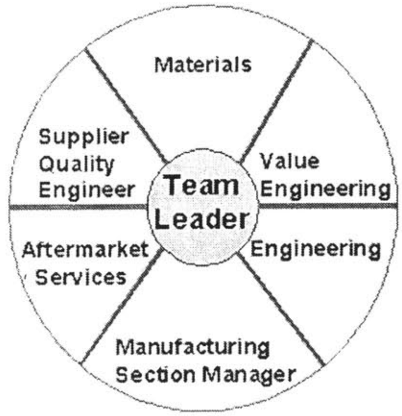

Figure 10 – Cross-functional Sourcing Wheel

The sourcing wheels identify items to outsource and coordinate activities and resources throughout the entire outsourcing process.

3.3.4 Phase Gates

In proceeding through the outsourcing process, a project must receive an official approval from the steering committee at various stages to proceed to the next phase. The sourcing wheel is responsible for ensuring all requirements are complete prior to meeting the phase gate with the steering committee. The following figure, which is taken from a bi-weekly project review, indicates the location of the phase gates with respect to the entire outsourcing process.

Phase Gates

	ID Suppliers	Down Select to key Suppliers	RFQ Released	RFQ Received	Visit (if req.) and Down Select	Negotiation Strategy/ Negotiation	Establish inventory transfer schedule/establish cut-in date	Award	PDA& Test	First Article Build	First Article Qualification	Production Cut-In
Timeline	11/30/01	1/25/02	2/1/02	4/12/02	5/15/02	6/30/02	6/30/02	6/30/02	9/30/02	10/30/02	12/15/02	1/30/03
Actuals				7/17/02	8/16/02	9/30/02	10/15/02	10/11/02	11/4/02	12/9/02	12/18/02	1/30/03

Figure 11 – Phase Gates for Strategic Outsourcing Process

As can be seen, there are three phase gates prior to contract award with one remaining phase gate after the completion of the "First Article Build" by the supplier. There are essentially three decisions that can be made by the steering committee at each phase gate:

Approve and proceed to the next phase; Reschedule phase gate after resolving the steering committee's concerns; or Cancel the outsourcing project.

3.3.5 Subcontract Administrators

Once the contract has been awarded the subcontract administrators are primarily responsible for managing the supplier, while the sourcing wheel plays a lesser role. The subcontract administrator is responsible for managing the program costs, quality, delivery, negotiations, contract modifications, and general supplier relationship. However, the sourcing wheel can still be utilized to generate cross-functional support when problems arise requiring operational resources.

3.4 The New Product Development (NPD) Process

Axcelis follows a very structured and methodical NPD process, which is called "Product and Cycle-Time Excellence (PACE)." The PACE process was developed by the management consulting firm Pittiglio Rabin Todd & McGrath (PRTM) to manage product development as a process [McGrath 1992].

3.4.1 Product and Cycle-Time Excellence (PACE)

The PACE process is founded on three key elements: a phase review process, core teams and structured development. The phase review process is meant to bring all decision makers together at once so a decision can be made. This group of senior managers is referred to as the Product Approval Committee (PAC). The core teams are based on the concept of a cross-functional team empowered to concurrently develop the product. The product development process is comprised of six top-level phases: proposal, definition, design, verification, validation and production. Axcelis breaks each phase down two more levels into detailed steps and tasks. The PACE process is designed to be very comprehensive, which results in numerous tasks which are not applicable for specific projects. From that perspective, the process can be cumbersome and somewhat unwieldy. On the other hand, if the process is followed by all of the key players throughout the organization it can be extremely helpful in planning and coordinating the extensive amount of resources required to complete each phase. Similar to the strategic outsourcing process, PACE includes a phase gate at the end of each phase.

Phase 0: Proposal

During the initial phase the company is trying to prove that a particular concept can be developed into a functional product, as well as verify that a legitimate market opportunity exists for the product. Typically this includes the creation of a business proposal, a product concept document and a market assessment. At the end of this phase the PAC will issue a "Go" or "No Go" decision.

Phase 1: Definition

The primary objectives of Phase 1 are to clearly define the product requirements and to create a comprehensive plan for the remaining four phases of development. Key deliverables of this phase are a product requirements document, a product marketing plan, and a business plan which includes functional plans such as a technical development plan and a purchasing and logistics plan.

Phase 2: Design

The majority of the product design and development occurs in this phase. The objective is to complete the required drawings, documents and software required to build a functional prototype. In addition to the design, subsystems are tested and many of the support processes are initiated in this phase. Examples include: System test plan, manufacturing processes, supply chain plan, and aftermarket services plan.

Phase 3: Verification

The majority of system level testing is completed and the design is finalized during Phase 3. All of the subsystems are integrated into a complete system, which is then tested to ensure system performance specifications are met. All relevant plans are updated as required. Manufacturing tools and processes are nearly complete.

Phase 4: Validation

The primary role of Phase 4 is to validate the production processes and tools, and to prepare for the transition from design and testing to production. The first products off of the line are evaluated to ensure that both customer and market requirements are met. The product launch plan is finalized and the aftermarket service plan and production release plan are executed in preparation for production.

Phase 5: Production

During the last phase of the development process manufacturing is ramped up to full rate production and the product market launch occurs. The initial products are distributed and aftermarket services are initiated. In addition, plans are developed to ensure continuous improvement of production processes. At the end of this phase product responsibility is transitioned from the product team to functional departments.

3.4.2 Integration of Outsourcing Process within PACE

Tasks related to outsourcing are included in each of the six phases of the PACE process. Axcelis has worked to update the PACE process to include links with the newer strategic sourcing process. While the processes are now linked, the PACE process simply identifies the task to be completed. Product development teams must still turn to the strategic sourcing process for tools and specifics on outsourcing.

Several features from PACE have been designed into the strategic sourcing process. For example, the steering committee, sourcing wheels and phase gates in the sourcing process are all are patterned after similar features in the PACE process. PACE was implemented at Axcelis roughly two years before the strategic sourcing process. While PACE is not being followed exactly as implemented throughout the organization, the majority of the participants attempt to use the process. This has benefited Axcelis in creating a standardized process that has reduced both risk exposure and duplicate efforts in the development process.

3.5 Shortcomings of Existing Processes in Outsourcing Engineering Design

At the highest level, the 14-Step sourcing process is generic and would apply for an engineering design outsourcing effort. Each identified step will typically occur in nearly any strategic sourcing effort whether the focus is on outsourcing manufacturing, engineering or both. However, down at the tactical level several of the tools developed for sourcing manufacturing and production are inadequate for engineering design sourcing projects. Furthermore, there are no mechanisms within the current tools and processes to identify the roles and responsibilities of each functional group in a cross-functional sourcing effort.

3.5.1 Outsourcing Candidate Selection Process

Axcelis created a strategic sourcing workshop to identify product assemblies as possible outsourcing candidates. The workshop reviewed the strategic importance of retaining the design, development and manufacturing capabilities of each product assembly. Several factors used to assess the strategic importance are shown in the figure below which represents a model developed by PRTM, Inc. and Clockspeed, Inc.

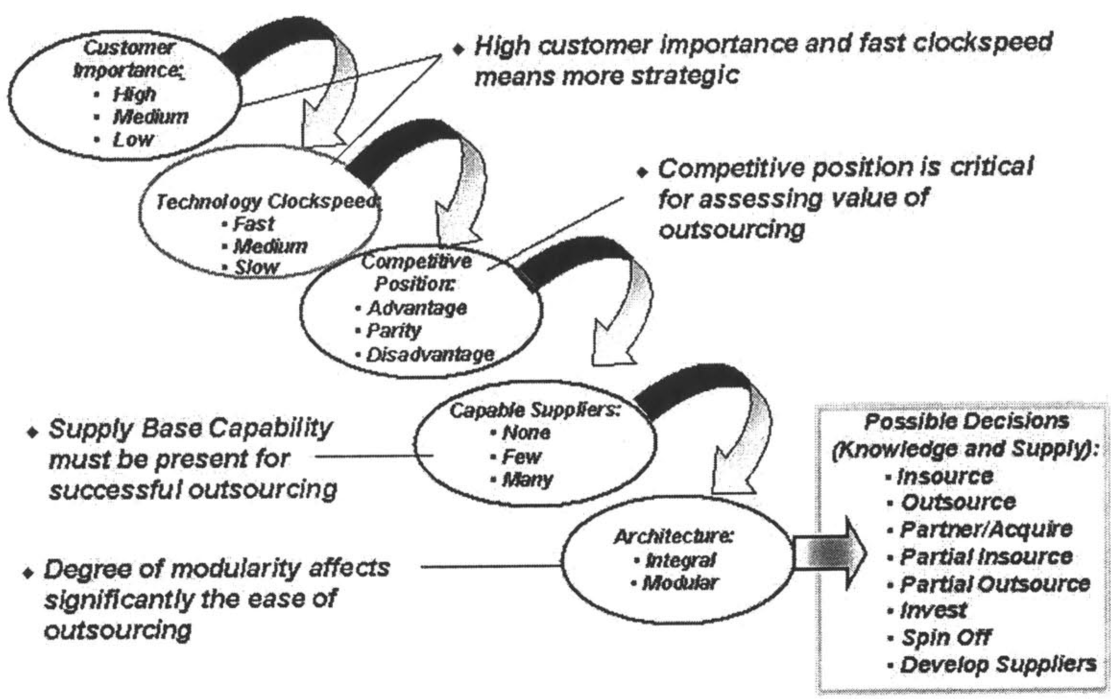

Figure 12 – Factors Used to Assess Strategic Importance [Fine, p. 52, 2003]

The model was used effectively to select potential outsourcing candidates for manufacturing. The decisions were made strategically at a high level.

However, on the engineering side outsourcing candidate selections are made on a product-by-product basis. Previously, most Axcelis product designs were extremely integrated and did not lend themselves to outsourcing. Currently, new products are being designed with a focus on modularity to facilitate manufacturability, service repairs and outsourcing. Assembly outsource selections are based primarily on available resources at the product level. While convenient and possibly even advantageous in the short term, the product-by-product outsourcing decision process can negatively affect the company's vertical integration strategy. Instead of establishing and managing the vertical integration strategy at a high level, each individual product outsourcing decision drives the strategy. In the worst case scenario a company might eventually lose a critical capability by default, rather than through a carefully managed vertical integration strategy as described in Section 2.2. Engineering needs to follow a similar model as that of Operations. However, additional criteria should be considered as well. Once the vertical integration strategy has been established, potential outsourcing candidates need to be effectively prioritized. While the architecture should play a role in the prioritization process, available resources, expected return on investment and availability of suppliers should also be considered.

3.5.2 Request for Proposal and Contracting Tools

The tools, which were developed to support the process of seeking supplier bids and contracting services with the winning supplier, were created specifically for the purpose of outsourcing manufacturing.

Statement of Work (SOW)

An existing SOW covered every aspect of the manufacturing outsourcing effort from first article build through delivery of final products. The SOW was very comprehensive and applied to essentially all outsourced manufacturing efforts with little to no modification required. However, this is precisely why it would not function for the outsourcing of engineering design. In outsourcing engineering design each effort was very unique. For example, in certain cases a supplier was expected to provide a validated design with a working prototype, while in other cases the supplier was expected to provide the design only. Even in design-only contracts there is a wide range of variability in both the actual services required and contract deliverables. A flexible SOW is needed which captures requirements which are common to all design outsourcing efforts while providing the flexibility to include all unique requirements of a particular outsourcing effort.

Partnering Agreement

A partnering agreement was established to specifically define quality, warranty, purchase orders and other key requirements. The agreement is not sufficient for a design outsourcing effort. Critical issues that are not covered include: intellectual property ownership, design liability, confidentiality, and a payment structure based on completion of product development phases.

Product Technical Performance Specifications

A key tool that did not exist for the manufacturing process was a technical performance specification for the item to be outsourced. The goal of the performance specification is to describe what is wanted in terms of performance and interface requirements, without directing a specific method for achieving it.

Supplier Assessment Tools

Axcelis had previously developed a Pre-assessment Survey to be completed by the supplier prior to a site visit, as well as the Commercial Assessment Survey, which was completed by Axcelis personnel after a site visit to the supplier's site. Both tools required modification to include assessment categories specific to engineering design, which would be relevant to the source selection process.

3.5.3 Functional Roles and Responsibilities

In outsourcing manufacturing, the operations division handled all aspects of the process from outsourcing candidate selection to contract award. However, in outsourcing engineering design the strategic sourcing group under the operations division would be working hand in hand with the selected product team from the engineering division. While the steps to be taken are clearly identified the group responsible for completing each action is not clearly specified.

In the past, engineering outsourcing efforts were completed on an ad-hoc basis without following an established process or framework. This lack of an overarching sourcing process for engineering design compounds the difficulty of defining which tasks engineering must complete. To ensure the strategic sourcing process is capable of handling engineering design sourcing projects, the tasks and responsibilities of both organizations must be clearly defined.

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Chapter 4: Organizational Processes and Dynamics

4.1 Chapter Overview

In Chapter 3, the existing outsourcing and new product development processes were explored, as well as the shortcomings of the existing processes with respect to engineering design outsourcing. However, the chapter focused primarily on processes, and did not delve into the organizational structure.

Chapter 4 investigates the existing organizational dynamics that affect the engineering design outsourcing process. The organization is explored from three perspectives: strategic design, political, and cultural. Primary focus is on the Operations and Engineering Divisions. Insight gained from the various perspectives is used to orchestrate effective change management during the internship project. Organizational change management is analyzed during three critical phases: building momentum, visionary change, and refinement.

4.2 Three Lens Model

A critical objective of the project is to create the necessary organizational linkages to facilitate cross-functional communication, collaboration, and decision-making. To establish a successful internal process to outsource engineering design, groups from both Operations and Engineering must work closely together throughout each phase of the process. To gain a clearer understanding of the organizational dynamics affecting the project, I relied on an organizational process model, which analyzes an organization from three distinct perspectives or lenses as seen in the following figure.

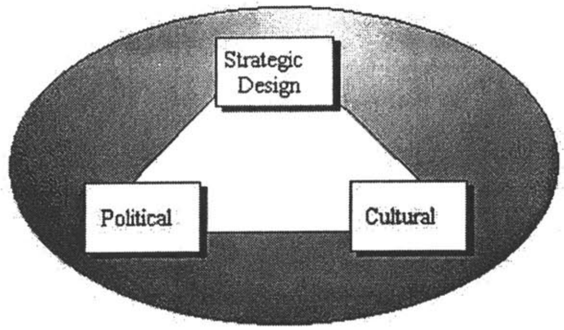

Figure 13 – Three-Lens Perspective of Organizational Processes [Kochan 2003]

> **<u>The Strategic Design Lens</u>**
> Looks at "How the flow of tasks and information is designed, how people are sorted into roles, how these roles are related, and how the organization can be rationally optimized to achieve its goals" [Ancona, M-2 p.7, 1999]
>
> **<u>The Political Lens</u>**
> Looks at "How power and influence are distributed and wielded, how multiple stakeholders express their different preferences and get involved in (or excluded from) decisions, and how conflicts can be resolved.
> [Ancona, M-2 p.8, 1999]
>
> **<u>The Cultural Lens</u>**
> Looks at "How history has shaped the assumptions and meanings of different people, how certain practices take on special meaningfulness and even become rituals, and how stories and other artifacts shape the feel of an organization.
> [Ancona, M-2 p.8, 1999]

This section explores the internship project as it relates to both the Strategic Sourcing Group within Operations and an engineering product design team within Engineering from the three-lens perspective.

4.3 Strategic Design Lens

4.3.1 Operations Roles and Responsibilities

The primary owner of the engineering design outsourcing process being developed on the internship is the Strategic Sourcing Group, which falls under the Operations division. The Operations division is tasked with the materials management, manufacturing, assembly, delivery and aftermarket service of all Axcelis products. During the time of the internship project the Operations division was in the midst of significant change due to a major consolidation effort. Previously, Axcelis had two key manufacturing sites at Beverly, Massachusetts, and Rockville, Maryland. In an effort to reduce cost and to improve cross product integration, Axcelis decided to move all manufacturing operations to the Beverly, Massachusetts, location. The effects of the consolidation were felt throughout the organization, as the two former groups worked to integrate at all levels of the organization. The organizational layout of the Operations division is illustrated in the following figure.

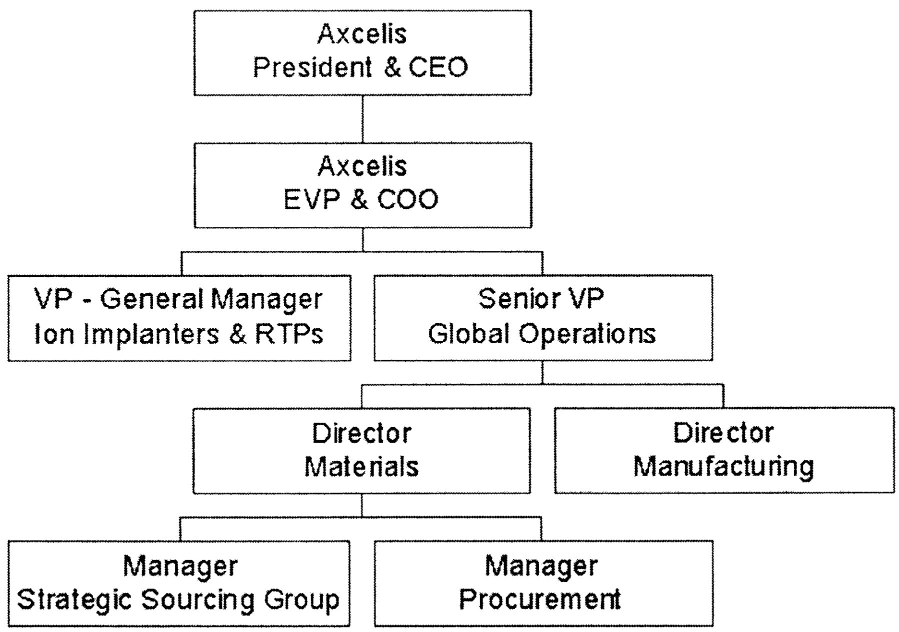

Figure 14 – Simplified Operations Organizational Structure

The materials group contained a tactical procurement section, which supports manufacturing and engineering prototype development, and the Strategic Sourcing Group, which manages outsourcing efforts. All external contracting and purchasing throughout the organization fell under the auspices of the Director of Materials. The tactical procurement groups were responsible for commodity type purchases of both service and materials. The Strategic Sourcing Group was created to manage all significant outsourcing projects related to either manufacturing or engineering design.

As can be seen the materials management groups are divided up by activity in a functional manner. However, cross-functional project teams typically conduct actual projects. The Strategic Sourcing Group utilized a cross-functional team, which was referred to as a Sourcing Wheel, to implement the original 14-Step sourcing process. A description of the sourcing wheel is found in Section 3.3.3. Initial outsourcing efforts were comprised of manufacturing projects. All groups affected by the outsourcing efforts fell under the control of the VP of Operations. Although Strategic Sourcing did not have direct control over the other operational groups, they did have strong support from the VP of Operations. In contrast, the proposed engineering design outsourcing efforts involved groups such as the engineering product design team which did not fall under the purview of the VP of Operations. Conflicts arising during process implementation and execution could not be resolved within the same division. Strategic Sourcing had the responsibility for facilitating the outsourcing process, but had limited authority in working with engineering.

The internship project's objective of formalizing the outsourcing process through the use of common processes and tools was appealing to the Strategic Sourcing Group. First of all, it would provide a fairly robust process that reduces risk exposure to the previously mentioned concerns. If implemented successfully, engineering would be more likely to support the new process for outsourcing engineering design and would accept a higher level of involvement by the Strategic Sourcing Group. In addition, Engineering's support would help to legitimize a process that was being sponsored by the Strategic Sourcing Group. Little to no changes in Operations' organizational structure were required to implement the process. The Strategic Sourcing Group, which would be Operations' representative working with Engineering, was already organized and functioning.

4.3.2 Engineering Roles and Responsibilities

The engineering division is arranged in a typical matrix organizational structure. Engineers fall under a specific function representing their particular expertise. Examples of engineering functional groups at Axcelis include controls, end station and beam line.

Most engineers, however, do not reside with the functional group, but are assigned to specific product teams as the expert in their particular area of expertise. The organizational structure of engineering can be seen in the following figure.

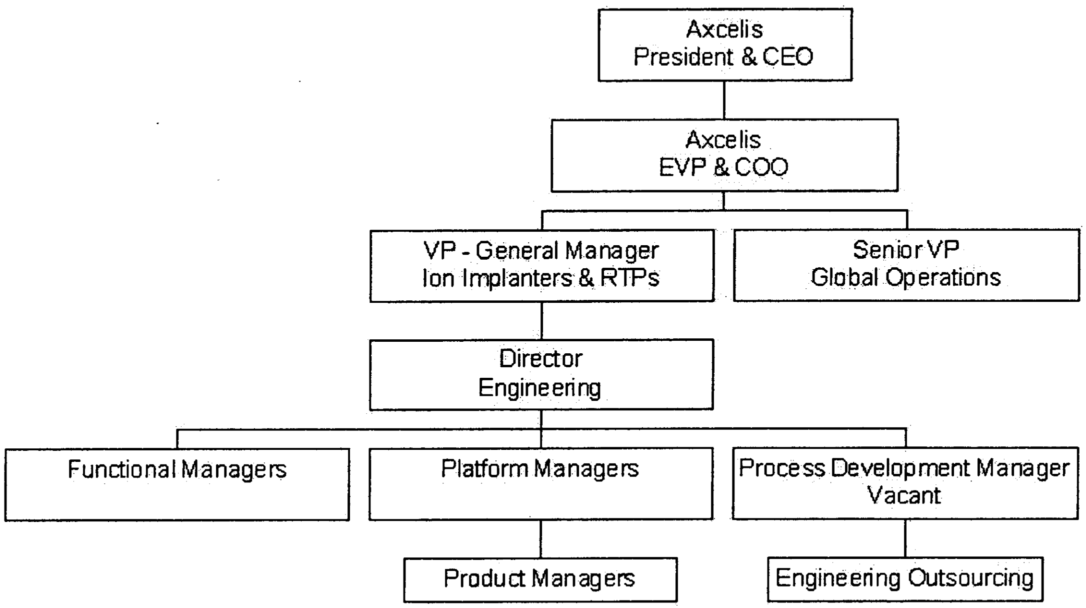

Figure 15 – Simplified Engineering Organizational Structure

An engineering product design team is led by a product manager, who reports to a platform manager, who in turn reports to the Director of Engineering. A platform represents a particular product line of tools. Examples of ion implanter platforms include high current, medium current, and high-energy tools.

Engineering is primarily concerned with the product performance requirements and time to market schedule established by marketing. The rapid pace of innovation in the high tech industry drives the need for constant product improvements and upgrades. In the past, Axcelis has performed the vast majority of engineering design in house. A standardized process did not exist to assist lead project engineers in selecting and contracting key suppliers. There are examples of failed projects that could have been avoided through a formalized process. Examples include selecting suppliers without the necessary resources, such as the appropriate engineering design software programs, and contentions over design ownership due to lack of clarity in the contract agreement.

In general, the engineering division is supportive of the project and recognizes that many of the previously unsuccessful engineering design outsourcing projects could have been avoided or lessened through a comprehensive outsourcing process. Furthermore, the company's strategic focus on outsourcing non-core functions and capabilities is influencing Engineering's desire to reduce the risk exposure associated with engineering design outsourcing. The primary concerns Engineering has with the project are the ability of the process to rapidly respond to Engineering's needs and the personnel resources required to administer the process. The product design effort follows a very rigid schedule in order to meet the established time-to-market completion date. It is difficult to identify the detailed performance specifications of an assembly early in the product development process. However, once the specifications have been established there is typically a tight schedule to meet with little lag time. The outsourcing process must be responsive enough to select and contract a supplier without adversely affecting the overall product design schedule.

The greatest organizational challenge of the project was to establish an organizational structure within Engineering to help coordinate the implementation and execution of the engineering design outsourcing process. A senior member of the Engineering Processes Group was given responsibility for the engineering design outsourcing effort in Engineering with the help of two assistants. This person facilitated the integration of the Strategic Sourcing Group with engineering product design teams and helped to establish and communicate the process changes throughout engineering.

4.4 Political Lens

4.4.1 Key Stakeholder Map

The primary stakeholder map identifies specific individuals or groups which are affected by the engineering design outsourcing process and their support, or lack thereof, for the project.

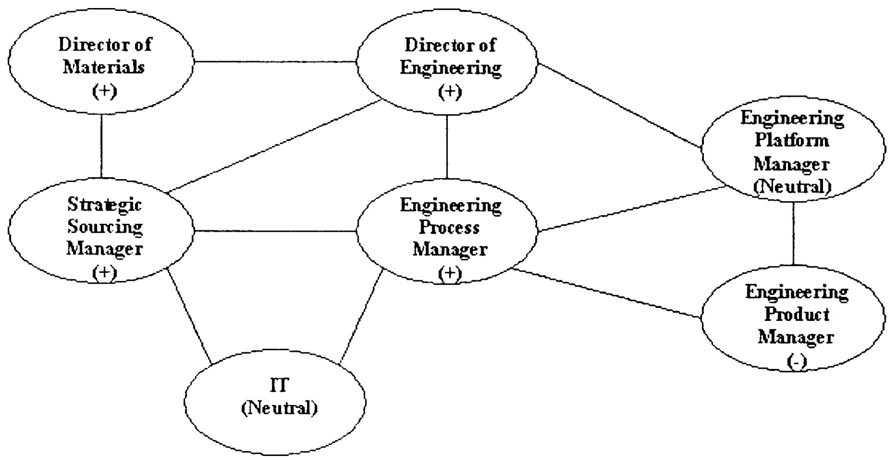

Figure 16 – Key Stakeholder Map

Specific individuals or groups are represented by labeled ovals. The lines between ovals represent interaction between these individuals or groups relating to the engineering design outsourcing project. Actual level of support from each individual or group for the project is shown by either a "+," "Neutral," or "-" symbol within each oval. A "+" implies active support and participation for the project. A "Neutral" implies an indifference that is typically shown by a verbal support for the project with a lack of active participation. A "-" implies opposition to the project that is typically shown by frequent verbal criticism, or actual efforts to bypass or halt the process.

The stakeholder map assists in understanding the organization's political environment, which is critical to a successful implementation of a business process. Strategies can be formed for gaining process approval, as well as for working with specific groups or individuals. Furthermore, it can assist in identifying early on potential roadblocks within the organization.

4.4.2 Operations Stakeholders

The Director of Materials is the most senior stakeholder involved in the project on the Operations side in terms of position level in the organizational structure. The Director of Materials is responsible for all product supplier relationships within the Beverly, Massachusetts, facility. This includes the management of procurement efforts for commodity components, as well as the management of outsourced design and manufacturing efforts. Any previous engineering design outsourcing efforts were managed solely by Engineering. With the new corporate focus on outsourcing non-core capabilities, several outsourcing initiatives have been started. The Director of Materials wants to improve the communication and integration between Engineering and the Strategic Sourcing Group in order to both enhance supplier selection and to lessen the likelihood of unsuccessful outsourcing initiatives.

The Strategic Sourcing Group is responsible for actually assisting Engineering in selecting and contracting suppliers and strongly supports the project. The Strategic Sourcing Group is the operational group most affected by the project. The successful implementation of an engineering design outsourcing process will greatly influence the frequency and type of interaction between the Strategic Sourcing Group and engineering product design teams. The Strategic Sourcing Group has benefited from strong support at the executive level for the non-core capability outsourcing initiatives. However, they cannot rely solely on executive support to achieve success in cross-functional outsourcing projects. The Strategic Sourcing Group is essentially the project sponsor and has the most interest in seeing it implemented successfully.

4.4.3 Engineering Stakeholders

The Director of Engineering is the most senior stakeholder involved in the project on the engineering side in terms of position level in the organizational structure. The director is the most pivotal stakeholder in the entire process. Without strong support and backing for the project by the Director of Engineering, the engineering product design teams and platform managers will not follow the engineering design outsourcing process. In addition, Axcelis is primarily a technology driven company. While operational excellence is important, it plays a lesser role than the technical capability of the products. If Engineering feels that a structured engineering design outsourcing process adversely affects their ability to meet the product performance specification and time-to-market deadline the process will be terminated. Fortunately, the Director of Engineering's support is fairly strong. He recognizes the inherent risks associated with design outsourcing and the need to ensure the supplier complies with the intellectual property ownership, design liability, confidentiality and design feasibility requirements imposed by Axcelis. However, he is also reluctant to create a senior level cross-functional steering committee to oversee the process since it might add additional delay to actual project approvals. The steering committee is crucial to the continued support of the process and the ability to make cross-functional decisions jointly.

The engineering product design teams are responsible for actually following the process and working with the Strategic Sourcing Group to select and contract suppliers. Support of the process is primarily based on the personal opinions of the product managers. In general, the product managers are not strong supporters of the process. From their perspective it is an added complication to an already intensive new product development process. One key concern is the time requirement placed on key engineering personnel. To outsource effectively the team must dedicate time up front to identify both the technical performance specifications of the outsourced assembly design as well as the deliverables to be completed by the supplier. Up front planning takes time and can be unpopular especially if it is viewed as a new requirement. The other concern is the loss of autonomy. In the past, lead engineers were free to select the suppliers they wanted and were able to bring them on quickly with very loose or non-existent contracts. If both the platform managers and the Director of Engineering support the new process, then the product managers will have limited influence in opposing the process. However, if there is not strong support for the process from above, the product managers could easily obstruct the daily execution of the process.

As a group the platform managers are more supportive of the process than the product managers, but are not strong supporters. The platform managers are not as concerned with the time required up front by the product team to identify the outsourcing requirements. In fact, they value the information generated by the planning process. However, a formalized process does remove some of the decision-making authority previously owned by platform managers. For example, the process is divided into steps and phases some of which require steering committee approval to proceed. Previously, the platform manager had the ability to proceed at their discretion. This group is also critical to the success of the project since they are close to the Director of Engineering and can influence his decisions.

4.4.4 Political Summary

Both Engineering and Operations have the desire to reduce risk exposure through a formalized sourcing process. The objective of the Strategic Sourcing Group is to establish relationships with desirable suppliers, and to ensure mechanisms are in place to limit potential risk factors. In addition, Operations wants to ensure Engineering communicates their outsourcing requirements with sufficient time to prepare without jeopardizing Engineering's schedule requirements. The objective of the engineering product design teams is to ensure that suppliers are both technically competent to perform the work, and are capable of completing the work within the schedule and cost constraints. Engineering is interested in seeking the assistance of the Strategic Sourcing Group to help with the source selection process as long as their involvement does not hinder the process. In general relationships between the two divisions on previous sourcing projects has been positive.

4.5 Cultural Lens

Axcelis as a company is seeking to establish its own culture and identity. In 2000, Axcelis spun off from the Eaton Corporation as an independent public company after 20 years as a division within Eaton. As an independent company Axcelis has the potential to be much more dynamic and responsive than previously, due to the smaller size and single focus on the semiconductor industry that resulted.

As a technology driven company, Axcelis placed significant emphasis on technological capability. Operational processes and best practices were of less importance to the company. Engineers focused on reaching objectives as quickly as possible using any means necessary. Lean enterprise initiatives were not implemented until after the corporate spin off from Eaton. The culture has resisted the transition to more formally structured operational practices, especially in Engineering. The Operations division started the transition sooner than Engineering due to Lean enterprise initiatives. Certain procedures did exist in operations, however lean initiatives worked to streamline and formalize several processes. The strategic sourcing initiative soon followed, requiring a methodical process to select potential non-core capabilities to outsource, and to manage the selected suppliers.

As a project sponsor, the Strategic Sourcing Group strongly influenced the structure of the developed process. The project represented the group's focus on creating a methodical process, which could be broken into specific steps and phases. Tasks, tools and procedures could be developed to support the entire process. This project represents the first big initiative by the Strategic Sourcing Group to extend this framework outside of the Operations division.

The engineering group viewed the project as a necessary step in the inevitable transition towards a formalized outsourcing process. My project was presented to the Engineering group as the next phase of the 14-Step Sourcing Process, which had been utilized to outsource manufacturing tasks during the first phase.

4.6 Insight From Three-Lens Perspective

Analyzing the internal divisions from three perspectives greatly assisted in gaining an understanding of the organizational dynamics at Axcelis that were affecting the project. Although the engineering design outsourcing process would be administered jointly by

Engineering and Operations, the key to a successful process implementation remained with Engineering. This insight was born out by all three perspectives. The strategic design of the organization was functional. Strategic Sourcing fell under Operations, but was given responsibility for the outsourcing efforts within Engineering. Engineering essentially had the option to coordinate with Strategic Sourcing as desired, since it was difficult to enforce a process from Operations in Engineering. The keys politically within engineering were both the Director of Engineering and the Platform Managers. The Product Managers posed the greatest opposition, but would essentially follow the will of the Platform Managers especially if they strongly supported the process. Even culturally Engineering was not accustomed to rigid processes and would resist the new processes more than Operations.

Two key actions were influenced early on in the process implementation due in part to this insight. First of all, the decision to locate my office in Engineering versus Strategic Sourcing helped me build relationships of trust and to keep a close eye on the implementation progress. This allowed me to interact much more frequently with key engineering members and led to several invitations to both formal and informal discussions of the process. Secondly, the establishment of the Cross-Functional Working Group was deemed paramount to the success of the project and was given a high priority.

4.7 Organizational and Leadership Challenges

A significant portion of the project involved organizational change initiatives. In order to explore the leadership challenges associated with organizational change I will use the Sloan Leadership Model framework.

4.7.1 Sloan Leadership Model

The organizational change process proved to be the most difficult portion of the project. To assist in describing and analyzing the change process that took place, I will utilize the MIT Leadership Model for Catalyzing Action and Change, which is illustrated in the following figure.

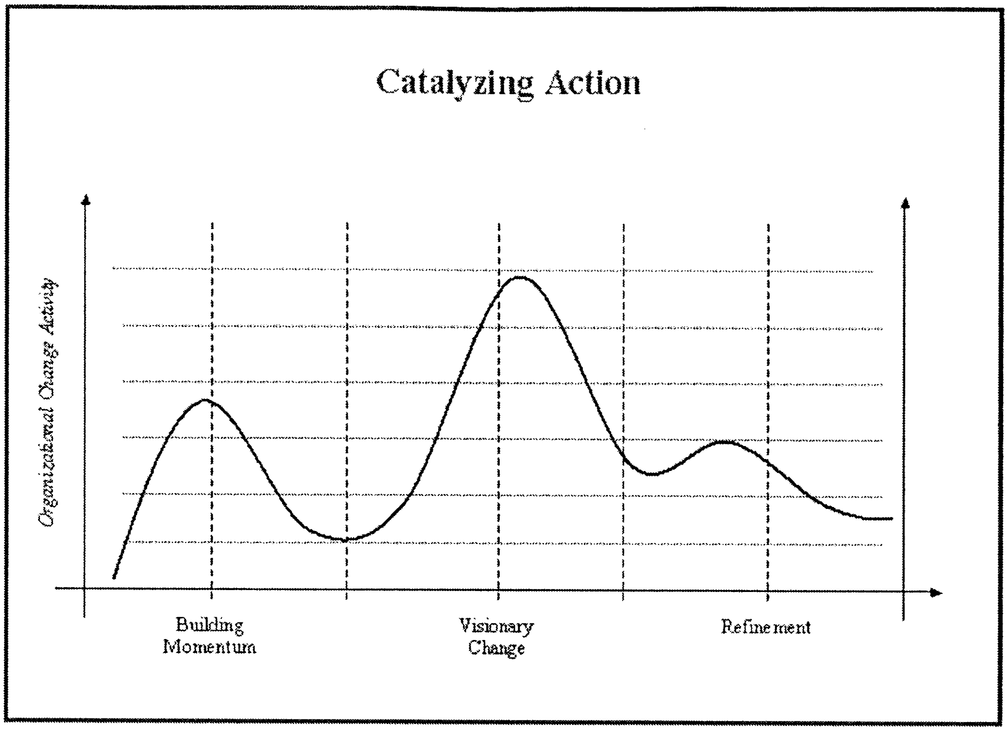

Figure 17 – Sloan Leadership Model—Catalyzing Action [Kochan 2003]

The primary phases of the Catalyzing Action framework include: building momentum, visionary change, and refinement. The key functions used to implement the leadership model compromise a leadership change signature, which include: sensemaking, relating, visioning, and inventing.

4.7.2 Building Momentum

The first two to three months of the internship were spent on building momentum for the project. To gain a thorough understanding of both the organization and the current outsourcing process I spent time interviewing people in numerous different roles and functions. The interviews were invaluable to not only understand the technical merits of the outsourcing process, but to also understand the structure of each division and the politics involved. The objective of each interview was to understand the individual's thoughts about what is happening in the organization and their vision for a successful outsourcing engineering design process. In addition, I observed the current process execution. Probably the most valuable activities I observed were actual contract negotiations with various suppliers. The negotiations provided insight into the chief concerns of the supplier and ideas for gaining a win-win situation. With the insight gained I was able to identify the type of outsourcing process required.

The initial interviews also enabled me to build a critical network with key Axcelis personnel. By seeking their input from the start I was able to gain support and participation in the project. The relationship was mutually beneficial since they helped get the project off the ground, while I helped to improve their day-to-day work by incorporating their ideas and concerns into the design of the engineering outsourcing process.

The last and most significant step in the "Building Momentum" phase was the creation of the standing cross-functional working group to implement the engineering design outsourcing process. The team was composed of representatives from Engineering and Strategic Sourcing who would be responsible for not only implementing the process, but also for the management and execution of future design outsourcing initiatives. The team usually met weekly. The team was very successful in both communicating the different requirements of each functional group and making decisions with respect to the process. In addition, tasks were assigned each week as action items, which would then be reviewed at subsequent meetings until completed. The group was fairly successful at "boundary management." Senior functional managers were kept abreast of the cross-functional teams progress and were consulted prior to any major decisions.

4.7.3 Visionary Change

With the cross-functional working group in place and functioning we were able to create and implement the engineering design outsourcing process. Based on inputs received from interviews and the working group, tools were drafted to address gaps with the current process. Key ideas generated during the "Building Momentum" phase were solidified and approved. My primary role during this phase was to coordinate efforts and to maintain a focus on the objective.

One of the greatest challenges was communicating the new roles and responsibilities of both Engineering and Strategic Sourcing. The cross-functional team provided an ideal forum to identify key responsibilities jointly. As a team we prioritized actions such as tool creation, process training and initial outsourcing efforts. Members of the team were responsible for relaying information back to their respective groups. The goal was to create a process and test it with a specific product team involved in several outsourcing initiatives. By focusing the implementation on only a small section of Engineering we were able to clearly communicate the process and monitor its progress. While the process changed significantly it was manageable on a small scale.

4.7.4 Refinement

The selected product development team provided valuable feedback after piloting the process on several initiatives. Input was sought for both the tools created as well as the identified roles and responsibilities of each group. The cross-functional working group was responsible for reviewing the feedback and initiating changes to the tools and processes. Care was taken to introduce process changes in stages versus a continual process change to maintain interest. The stage changes also lessened the chance for confusion and misunderstandings.

The feedback received pertained primarily to the ease of use for internal Axcelis employees. More important feedback such as impacts to supplier relationships or contract deliverables was not obtainable during such a short period of time. However, during the initial phases of the process the objective was to improve both the level of supplier integration into the new product development process and the resulting deliverables.

During this phase of the project the ownership transitioned to the Strategic Sourcing Manager in Operations and the Engineering Process Manager in Engineering. My role shifted to that of a facilitator assisting the project leads as required. The transition proved quite natural since the managers selected from each division were active participants in the cross-functional working group.

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Chapter 5: Process Changes and Implementation

5.1 Chapter Overview

In Chapter 3 and Chapter 4, the existing outsourcing processes and organizational dynamics were discussed in depth. The resulting analysis helped to both highlight weaknesses with the current tools and processes, and also to identify the key groups and individuals that play pivotal roles in the success of the project. This information enabled the successful development and implementation of an engineering design outsourcing process.

Chapter 5 explores the development and implementation of the engineering design outsourcing process. The crucial role of the cross-functional working group is explained in detail. In addition, several of the tools and processes created during the internship project are introduced. Primary focus is on the request for proposal tools and the roles and responsibilities of the various players throughout the process. Finally, the chapter reviews the process implementation steps utilized during the project.

5.2 Cross-Functional Working Group

The establishment of a standing cross-functional working group was crucial to the success of the project. As discussed in Chapter 4, the Strategic Sourcing Group fell under Operations in the organizational structure, while engineering design outsourcing efforts were based out of Engineering. The cross-functional working group bridged the organizational divide between Engineering and Operations.

The group included the Strategic Sourcing Group Manager from Operations, the Engineering Outsourcing Process Manager from Engineering, and several individuals who worked under the two managers. Originally the team met every other week, however, during the implementation stage the team met weekly to coordinate efforts and to resolve problems as quickly as possible.

The team reviewed and approved all newly developed tools and processes, and established methods for improving cross-divisional communication. The team also coordinated the implementation of the new engineering design outsourcing process. The cross-functional nature of the team proved extremely useful since the team was able to jointly identify all schedule, training and resource requirements. In addition to process implementation, the team managed and coordinated actual engineering design outsourcing efforts. By the end of the internship, the process implementation was mostly complete and the team was focusing most of its efforts towards current engineering design outsourcing projects.

5.3 Tool and Process Creation

In many respects the development of the tools and processes proved much easier than the actual implementation and change management. During the first phase of the internship, the major shortcomings with the current outsourcing process as applied to engineering design were identified. The three significant gaps included: outsourcing candidate selection process, request for proposal and contracting tools, and functional roles and responsibilities. A description of each of the shortcomings associated with each of these items is contained in Section 3.5 of this thesis. The following subsections describe several of the solutions that were developed to improve the process.

5.3.1 Outsourcing Candidate Selection Process

Modification of the outsourcing candidate selection process was not undertaken during the internship. Several outsourcing candidates from products currently under development had already been identified. Axcelis was primarily interested in how to actually outsource the engineering design for candidates that had been previously selected. Suggestions for strategically selecting outsourcing candidates can be found in Section 2.2 of this thesis.

5.3.2 Request for Proposal and Contracting Tools

Several tools were created to facilitate the Request for Proposal (RFP) and contracting process. The most noteworthy tools developed during the project are briefly discussed in this section and include: statement of work template and instructions, partnering agreement contract, and technical performance specifications template and instructions.

Statement of Work (SOW) Template and Instructions

The existing outsourcing process had a generic statement of work document, which could be applied to nearly every manufacturing effort with little modification. The work requirements varied little since the type of work performed by the contractor tended to be fairly homogenous. However, for a design effort there is an extensive range of alternatives for projects. For example, the manufacturer might be outsourcing the design only or both the design and manufacturing. In addition, the suppliers might be working hand in hand with the engineers at the manufacturing firm to design the item jointly, or they might have sole responsibility. Thus a SOW for engineering design outsourcing must be flexible enough to handle such diverse scenarios.

The SOW was created with the intent of fulfilling the best practices discussed in Section 2.6.1. The overriding objective was to complete a SOW template that would allow Axcelis to state the supplier's duties in such a way as to ensure the supplier knew what was expected and could complete the project to Axcelis' satisfaction. A SOW written to this expectation would also allow the supplier to estimate the project cost, manpower, level of expertise and other required resources. In competitive bid situations this will assist Axcelis in comparing and contrasting the bidders proposals, because they will be based on the same criteria.

A template and instructions were created to assist Axcelis engineers in completing the SOW. The categories are general enough to apply to all situations, yet are also comprehensive enough to ensure that all the engineers have thought through the entire outsourcing scenario. The following table highlights the key sections of the SOW.

Section	Title
1.0	**Scope of SOW** This Section summarizes the breadth and limitations of the work to be done, the actions to be performed by the supplier and the results expected by Axcelis.
2.0	**Applicable Documents and Standards** Lists all documents referenced within the SOW by document number and title. Documents may include scholarly studies, technical publications, reports, standards, specifications and other references needed to clarify or support work tasks.
3.0	**Organization and Management Relationships** Identifies the Axcelis project manager(s), contract administrator(s) and other key personnel from both engineering and strategic sourcing.
4.0	**Technical Requirements**
4.1	Technical Objective and Goals Ensures design meets all requirements listed in technical performance specification. Additional technical objectives or goals can be included as necessary.
4.2	Design/Documentation Baselines Requires supplier to develop and update all drawings and specifications on Axcelis formats, including Bill of Materials, drawing trees, specification trees, and schematics related to the project until the period of time when the documentation package is turned over to Axcelis.
4.3	Interface Development Requires supplier to establish and work with Axcelis team to define and verify interface requirements in accordance with Technical Performance Specification.
4.4	Design Engineering Phases Should establish and define the specific phases of design for the project. Specific design tasks and associated deliverables for each phase should be identified under each phase.
4.5	Test and Evaluation Ensures supplier performs or supports all tests as described in either the Technical Performance Specification or other applicable documentation.

5.0	**Program Management Requirements**
5.1	Program Planning and Control Requires supplier to integrate design project into supplier's existing planning and control system which encompasses coordinated program scheduling, cost/schedule control, technical progress, cost reporting, management of program risks, and project information compilation and dissemination.
5.2	Financial Management Identifies any financial management expectations, as well as required billing and payment procedures.
5.3	Supplier Performance Requirements Clearly identifies performance targets and specific metrics, which will be used to gauge supplier performance.
5.4	Data Management Identifies supplier's data management and configuration control responsibilities. Reference applicable Axcelis and/or industry documentation standards which supplier should comply with. Include description of requirements such as labeling, tracking, archiving, controlling, etc.
5.5	Risk Management Requires contractor to perform risk analysis associated with meeting program costs, schedule and performance requirements. Analysis should identify potential risk areas, relative degree of risk, and recommend specific risk abatement alternatives. The results should be documented and presented during each design review.
5.6	Program Review and Reporting Outlines review and reporting expectations such as frequency and purpose of periodic meetings (face to face or teleconference), frequency and content of status reports, etc. In addition, it identifies the process for tracking and reporting status of any resulting action items.
6.0	Deliverables Lists each deliverable and provides a detailed description of what is to be provided. In addition, administrative details such as desired delivery format, due dates, delivery instructions, etc., should also be included.

Table 7 – Sections of the Statement of Work (SOW)

The SOW instructions include examples and recommendations to be used in tailoring the SOW to each individual project.

The template will allow Axcelis to give a standardized look to suppliers. Key suppliers will become familiar with the format, which will simplify future interactions. In addition, the standardized SOW and engineering design outsourcing process will allow the engineers to focus on development tasks versus the process itself.

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Partnering Agreement Contract

A design partnering agreement contract was developed jointly with Axcelis' legal department. A comprehensive contract was essential to reducing the risk inherent to engineering design outsourcing. Previous partnering agreements focused solely on manufacturing services and were not sufficient for an engineering design effort.

The partnering agreement focused on defining the design services, design ownership, design warranty, outsourcing schedule and price. As mentioned in Section 2.6.3, the contract typically does not accurately describe the actual working relationship, but provides a framework on which the relationship can be built and offers some recourse in case of a failed relationship. The following table lists some of the key sections of the contract.

Section Title

1 Design Services

Defines the specific type of services supplier is required to provide. In addition, to design specific services includes program management requirements such as schedule, budget, etc.

2 Time/Schedule

Establishes the official definition of contract commencement, completion, etc. Also defines the requirements for the contract to be considered "Substantially Complete" in accordance with the schedule.

3 Contract Price

Establishes the agreed upon price that Axcelis intends to pay the supplier. Also, discusses provisions and circumstances that would alter the price paid to supplier.

4 Progressive Payments

Discusses terms of payments. Payments are tied to completion of particular specified deliverables or services. Provides Axcelis with a specified period of time to review deliverables or services for completeness prior to payment.

5 Inspection

Defines the type of inspections, extent of inspections and reasons for inspection performed by Axcelis prior to accepting deliverables or services.

6 Buyer's Changes in Work

Establishes conditions under which Axcelis may submit changes to work requested, as well as the process for submitting changes.

7 Seller's Design Changes

Encourages supplier to develop improvements, but requires Axcelis approval prior to implementation.

8 Warranty

Requires supplier to warranty to Axcelis that all design work will be of good quality, free from faults and defects and in conformance with buyer's instructions, specifications, drawings, and data.

9 Correction of Work

Requires supplier to correct work that does not meet the agreement requirements. Outlines circumstances that warrant a "correction of work," provides process and schedule guidelines for "correction of work" effort by supplier.

10 Termination for Cause

Allows Axcelis to terminate contract if supplier breaches any provisions of agreement. Establishes procedure for terminating agreement.

11 Termination for Convenience
Provides option for Axcelis to terminate agreement for convenience. Establishes extent of compensation or benefits Zxcelis must provide supplier for such an agreement termination.

12 Confidentiality, Inventions
Requires suppliers treat all provided information as confidential. Also establishes the ownership guidelines for designs, drawings, processes, compositions of material, specifications, software, mask works or other technical information.

13 Escrow (Optional)
Requires supplier to place into escrow any intellectual property documentation it has developed in connection with this agreement and which is necessary for an alternative supplier to manufacture the items under this agreement. Supplier agrees to release this intellectual property documentation from escrow to Axcelis in the event the supplier defaults. In such a case, Axcelis gains the right to a limited sub-license of intellectual property documentation to be used for the development of contracted product either internally or by a third party.

14 Intellectual Property Indemnification
Requires supplier to take full responsibility for any claims, demands, or losses that arise from the supplier's infringement on any patents, trademarks, copyrights, etc.

Table 8 – Selected Sections of the Design Partnering Contract

Originally Axcelis desired to maintain complete design ownership since they were funding its development. However, in several instances suppliers were not willing to give up ownership, especially if they had developed the design previously at their own expense. In addition, suppliers lost the incentive to invest in future technology development and product improvements if they were not able to benefit by maintaining ownership of the design.

In response, Axcelis created an "Escrow" option. If Axcelis was not able to maintain ownership of the design, the supplier must place all intellectual property documentation in escrow. If the supplier defaulted on the contract, Axcelis then had the right to sublicense the intellectual property and release it to an alternative supplier for the purpose of supplying the sublicensed product to Axcelis.

The SOW and Technical Performance Specification (TPS) were included as attachments to the contract. As attachments these documents became legally binding. Thus the partnering agreement contract was fairly general and required little modification for each outsourcing effort. The specific details for each outsourcing effort were contained in the attached SOW and the TPS, which were each tailored to the specific outsourcing effort.

Technical Performance Specifications (TPS) Template and Instructions

The TPS was designed using the same methodology as the SOW. The TPS must be general enough to apply to all cases, yet the sections must be sufficiently comprehensive in scope to cover each area of concern. The template also allowed Axcelis to present a standardized specification, which fostered improved communication with suppliers since they became familiar with the Axcelis format and requirements.

The specification template focused on incorporating the best practices described in Section 2.6.2. The template can be used to describe both quantitative and qualitative requirements depending on the type of outsourcing effort as described in Table 5. The TPS might be completed entirely by Axcelis prior to awarding the contract. However, the TPS might also be developed jointly or solely by the supplier depending on the specific scenario. The TPS offers Axcelis the flexibility to involve a supplier during the early phases of the development effort before the detailed quantitative requirements have been identified. The key sections of the TPS are listed in the following table.

Section	Title
1.0	**Scope** This section should include a clear, concise description of the item to be designed. The intended use of the module may also be discussed. Requirements should not be contained in this section.
2.0	**Applicable Documents** Any outside document or standard referenced in this specification should be listed in this section.
3.0	**Requirements**
3.1	General States what is required of the supplier, but does not mandate how to do it. Typically requirements should not limit a contractor to specific materials, processes, parts, etc., but it can prohibit certain materials, processes, or parts if Axcelis has quality, reliability, or safety concerns.
3.2	Performance States what the item or system shall do in terms of capacity or function of operation. Any upper and/or lower performance characteristics should be stated as requirements, not as goals or best efforts.
3.3	Design Includes specific design requirements such as the use of particular components, materials, or design drawings. In addition, identify design for cost, manufacturability and maintenance requirements. Typically should minimize the use of "how to" requirements.
3.4	Physical Characteristics Gives specifics only to the extent necessary for interface, interoperability, operating environment, or human factors. Includes overall weight, size, dimensions, etc.
3.5	Interface Requirements States acceptable form and fit requirements of product to ensure both interoperability and interchangeability.
3.6	Material Should leave specific selection of material to contractor, but may include required materiel characteristic; e.g., corrosion resistance. Any detailed material requirements listed should be unique, critical to the successful use of the item, and kept to a

	minimum.
3.7	Parts Identifies any parts that will be used in the design. e.g. fasteners, electronic piece parts, cables, etc.
3.8	Operating Characteristics General description of how the item shall work.
3.9	Reliability States reliability requirement in quantitative terms. Must also define the conditions under which the requirements must be met. Minimum values should be stated for each requirement, e.g. mean time between failure, mean time between replacement, etc.
3.10	Service and Maintainability Specifies quantitative maintainability requirements such as mean and maximum downtime, mean and maximum repair time, etc.
3.11	Environmental Requirements Establishes requirements for humidity, temperature, shock, vibration, etc. and requirement to obtain evidence of failure or mechanical damage.
4.0	**Verification**
4.1	General Specifies all testing, inspections and analysis to be performed prior to acceptance to confirm that the outsourced item conforms to the requirements.
4.2	Testing and Inspection Conditions Describes the testing/inspection procedure, sequence of testing/inspections, testing environment, etc.
4.3	Qualification Identifies criteria used to determine whether the testing, inspection or analysis results met the requirements.
5.0	**Miscellaneous Requirements** Includes any additional requirements that are specific to the project.

Table 9 – Sections of the Technical Performance Specification (TPS)

The TPS instructions provide examples and recommendations to be used in completing the specification.

5.3.3 Functional Roles and Responsibilities

The cross-functional working group played a critical role in defining the functional roles and responsibilities. The Strategic Sourcing Group, from the Operations division, was responsible for managing all strategic outsourcing efforts at Axcelis. In particular, they offered support in selecting potential suppliers, evaluating bid proposals, and managing the contract through to completion. However, all previous strategic sourcing initiatives had belonged to the Operations division. In outsourcing engineering design, the Engineering division would be integrally involved.

To ensure a fluid process, the primary roles and responsibilities for both Engineering and the Strategic Sourcing Group were identified throughout the process. First of all the, the overarching 14-Step Outsourcing process was divided into five phases. The following figure illustrates the division of the outsourcing process into the five phases.

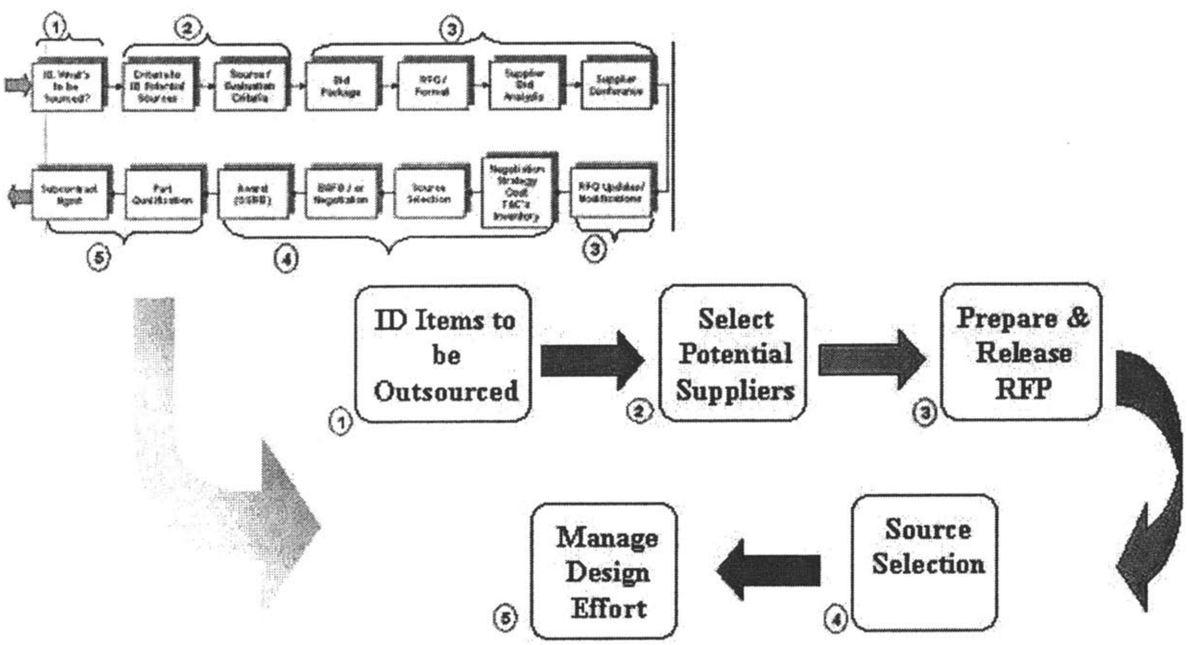

Figure 18 – Simplified Engineering Design Outsourcing Process

By simplifying the process into five phases it proved much easier to not only define the functional roles for each phase, but to also communicate the roles and responsibilities to Engineering. The 14-Step process overly complicated the process from Engineering's perspective. Strategic Sourcing continued to follow the 14-Step process internally, but integrated Engineering into the process via the five phases.

The cross-functional working group was able to define the roles and responsibilities jointly, and seek approval from both functional groups. Furthermore, the working group will continue to play an active role in managing on-going engineering design outsourcing efforts.

5.4 Methods of Implementation

The process changes were implemented through the cross-functional working group. Once the tools were developed and the roles and responsibilities were defined, the group laid out a plan to implement and communicate the process. The three key elements of the implementation process included pilot cases, development of an engineering design website, and key personnel training.

5.4.1 Pilot Cases

The Request for Proposal tools were piloted on several outsourcing projects associated with a new product currently under development. The project engineers involved in the outsourcing efforts were introduced to the new engineering design outsourcing process. The engineers used the SOW and TPS to prepare request for proposals. Since the outsourcing efforts were proceeding concurrently with the process design, each subsequent effort had not only more tools available, but more refined tools as well.

Project engineers provided feedback and suggestions for improvement after each use. For example, the instructions for completing the SOW and TPS were found to be unclear or insufficient in several places. Requests to change the top-level section categories were approved by the working group. In addition, several new tools or documents were identified as necessary for the RFP package. The Axcelis Technical Documentation Standards was a good example of a non-existing item that was identified as necessary.

A database was created of completed documents. The database was found to be extremely useful for subsequent projects, especially by engineers using the new templates for the first time.

5.4.2 Website Development

A specific website was developed to locate and maintain the engineering design sourcing process. The website is accessible to all Axcelis employees through the company intranet. Electronic copies of the strategic sourcing tools were placed on the website. In addition, process instructions, examples of completed documents and various other items are posted or will be posted shortly.

The maintenance and administration of the website will remain with the engineering process group. The website will maintain the latest versions of the sourcing tools and templates. An illustration of the website and some of the posted tools and processes is shown in the following figure.

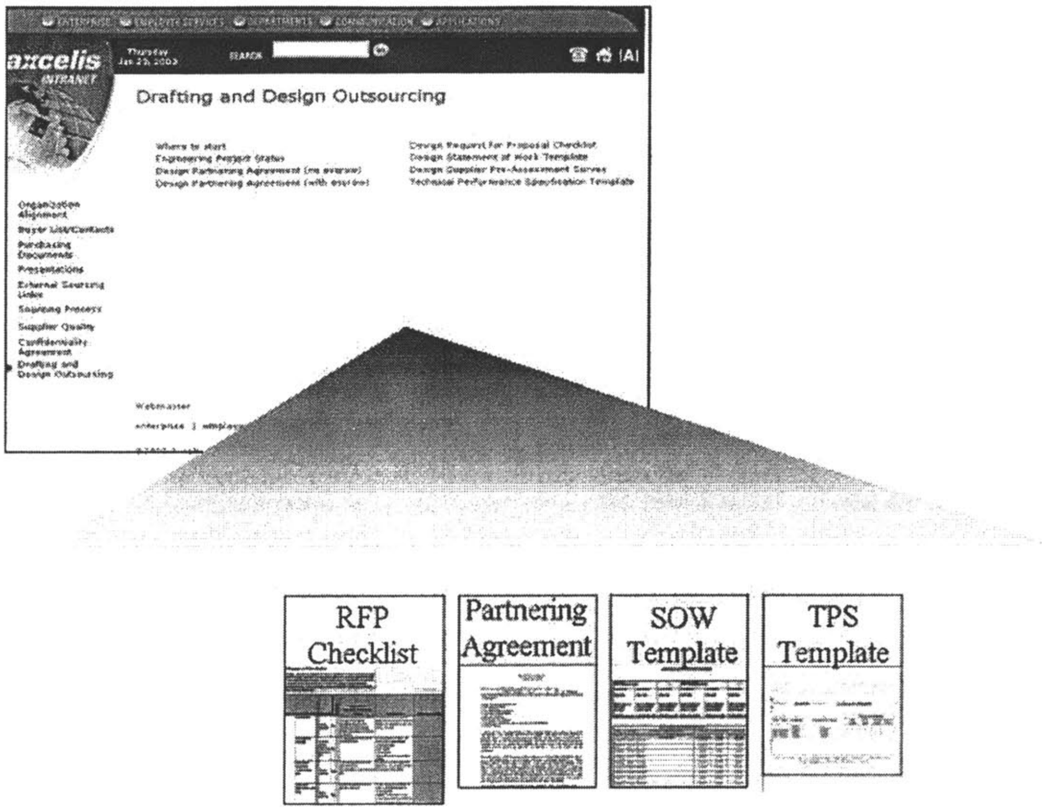

Figure 19 – Design Outsourcing Website and Selected Sourcing Tools

The website provided the ideal mechanism for maintaining and managing the process tools and instructions.

5.4.3 Key Personnel Training

During the project only the engineers involved with the pilot cases were trained on the process changes. However, a plan has been established to schedule all key engineering personnel on the process. Not all engineering personnel require the training. The targeted group of engineers includes platform managers, product managers and project engineers. Once the key personnel have been trained on the process, additional training can be provided to a broader group of engineering personnel on an as needed basis.

Key personnel training was intentionally placed behind the pilot cases and the website development. The working group wanted to wait for the completion of any significant revisions associated with the pilot cases prior to general release. In addition, the website would allow for the simplest mechanism to distribute the necessary instructions, tools and forms.

Chapter 6: Conclusions and Recommendations

6.1 Keys to Successful Engineering Design Outsourcing Process

In order to successfully establish and manage an engineering outsourcing design process, manufacturers must focus on three key aspects: outsourcing strategy, supplier management structure, and the tools and processes themselves.

Outsourcing Strategy

The goal of strategic outsourcing is to eliminate internal capabilities that are deemed either non-core or non-essential, allowing firms to focus resources on leveraging core competencies to maintain competitive advantages. However the decision to outsource individual capabilities must be integrally linked to the vertical integration strategy. A firm should actively select the desired level of vertical integration first, and then pick from the identified list of non-essential outsourcing candidates based on the desired level of vertical integration. Otherwise random outsourcing decisions will dictate the vertical integration strategy, since a series of uncoordinated outsourcing decisions will often lead to the loss of specific capabilities.

Supplier Management Structure

To achieve the desired benefits from engineering design outsourcing, the supplier must be effectively integrated into the company's new product development process. Prior to selecting a supplier, a manufacturer must identify the level of supplier integration desired based on both the internal resources available to manage the supplier, as well as the complexity and modularity of the selected item.

In order to maintain an enduring long-term partnering relationship both firms must benefit from a win-win relationship. Incentives must be designed to foster the desired win-win scenario for both parties. The Manufacturer can encourage supplier investment in technology development through long-term contracts, profit sharing, technology roadmap sharing, etc. In addition, the manufacturer must encourage active supplier participation in the new product development process.

Most importantly the manufacturer must dedicate the appropriate level of internal resources to properly manage the relationship. The internal management structure must be capable of providing internal coordination, eliminating both accountability and intervention problems, and improving knowledge management efforts. In addition, the outsourcing management group must be at a high enough level within the organization to maintain support and visibility across functional lines.

Tools and Processes

There are no set standards for the tools and processes used in engineering design outsourcing. Each firm must develop tools and processes that meet its particular needs. However, tools and processes should be developed to help with each major outsourcing phase: identifying items to outsource, selecting potential suppliers, preparing and releasing requests for proposals, source selection, and managing the design effort. Significant upfront planning is required to successfully execute an engineering design outsourcing process. The manufacturer should identify the level of integration desired, the services and deliverables required from the supplier, the development schedule, and preliminary product specifications prior to contract award. Without detailed upfront requirement planning the potential risks to outsourcing cost, schedule, and quality are significantly increased.

6.2 Summary

In today's competitive environment manufacturing firms must constantly seek to develop competitive advantages. By successfully integrating suppliers into the early stages of the new product development process, manufacturers can improve development times, lower costs and improve quality. However, the process of outsourcing significant portions of engineering design to key suppliers is risky and difficult to manage. No two outsourcing efforts are identical. An engineering design outsourcing process can be developed to guide manufacturing organizations through the supplier selection and integration processes, but each effort must be closely managed at various levels within the organization.

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