Image Engine Study:
Strategic Dynamic Control for
Low Volume Potentially High Mix Modules

by

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Bachelor of Science in Electrical Engineering
Brown University, Providence, RI 2000

Submitted to the Sloan School of Management and the
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ABSTRACT

The main goal of this project was to provide a case study on image engines for the purpose of developing a supply chain strategy. Initially, the current digital image engine manufacturing core competencies and respective capabilities were further defined and documented. Value chain maps were then developed for each line of business to assess Kodak's transition from analog to digital. The value chains clearly illustrate a lower reliance on consumables (including silver halide film and paper), and demonstrate an emerging capability in the digital equipment market. As image engine performance directly impacts the level of digital image quality, the study concludes that strategic dynamic control of these image engines is critical in order to maintain future competitive advantage.

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Title: Chrysler Leaders for Manufacturing Professor

Thesis Supervisor: Roy Welsch
Title: Professor of Statistics and Management Sciences

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I could never have made it to this point without the encouragement of my family. Thank you, Mom, Dad and Josh. And to David thank you for your continuing support.

During my time at Kodak, I was particularly impressed by the support and interest from all the members of the Digital Equipment Manufacturing Division team who gave me such a warm welcoming and truly made me feel a part of their team efforts. One individual who seemed to particular capture the spirit of the organization is Bill Wilson who died tragically during my time at Kodak. Wilson was a very knowledgeable and skilled technician who shared many of his insights with me during my work on the Mini-Fast Scan and was very supportive of my project. While he was never afraid to candidly express the realities of every day work, he remained an upbeat and positive individual. I will always remember Bill for his amazing vitality and passion for life.

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Chapter One: Introduction

1.0 Project Setting

The Digital Equipment Manufacturing Division at Eastman Kodak (subsequently referred to as Division A), manufactures digital equipment products and subsystems for the various lines of Kodak's business. These lines of business include Consumer Imaging, Professional Imaging, Document Imaging, Health Imaging, and Entertainment Imaging. The subsystems are designed as modules for the various lines of business and directly support systems such as Computer-Radiography equipment, Approval equipment, high-end scanners, LED printers, and projectors. The subsystems manufactured in Division A are most often referred to as image engines. Image engines are the low volume potentially high mix subsystems that produce the 'image capture'[1] or 'image output'[2] function for all digital equipment.

During the past few years Division A have lost several major contracts to both outside competitors and Kodak China. Subsequently the division has experienced significant downsizing, resource depletion, and budget cuts. Furthermore, as a result of this environment the lines of business have become increasingly insular and knowledge sharing between units is minimal. Therefore finding the appropriate individuals in each line of business to develop the knowledge base for this task was very difficult.

In order to conduct a comprehensive study the following critical issues were addressed:

- Define the current manufacturing core competencies and/or capabilities within Division A
- Define the value chains maps for the lines of business in the transition from analog to digital
- Examine the current and/or future image engine business strategy
- Identify the future image engine manufacturing core competency needs
- Data was collected and analyzed to assess the feasibility for an image engine platform

In addition, quality control was performed for the Mini-Fast scan, the subassembly for Health Imaging Computer Radiography 850/900. All of the information gathered for this work was then closely examined and synthesized into a series of recommendations.

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[1] The capture subsystem is defined as the optical, mechanical, and/or electronic precision aligned reading mechanism, this includes color calibration.

[2] The output subsystem is defined as the optical, mechanical, and/or electronic precision aligned writing mechanism; this includes characterization and artifact correction of the writing medium.

1.1 Thesis Overview

This thesis will provide a case study for image engines, the low volume potentially high mix subassemblies that directly support digital equipment. In order to provide the reader a comprehensive understanding of the importance of image engines and their role in maintaining firm *strategic dynamic control,* the work is presented as follows:

Chapter 2 illustrates the importance of planning, continuously improving, and implementing core competency development. Core competencies are fundamental to a firm's future performance. The creation of a center of excellence for competency development and renewal provides a firm with the ability to maintain dynamic corporate vision. Strategic corporate planning must be based on a continuous effort to identify emerging opportunities in the external environment, realigning firm core competencies to meet new market demand.

Chapter 3 defines the current core competencies and respective capabilities within Division A. The core competencies determined are as follows: sub-micron alignment of optical and mechanical systems, image system optimization, and image quality test and verification. These core competencies are leveraged across the lines of business in a wide variety of products.

Chapter 4 provides an analysis of quality control issues for the Mini-Fast Scan, the image engine in the Computer Radiography 850/900. The quality control measurements were defined and a database was created in SQL for data management purposes. Once the database was in place, a Gage R&R study was designed, implemented, and assessed for this subassembly. An ARIMA time series model was utilized to assess time dependency between subassembly batches. Lastly, statistical process control was implemented for this assembly process.

Chapter 5 provides an examination of the lines of business value chain maps. The value chain maps provide a high-level framework from which to assess Kodak's transition from analog to digital. Traditionally, digital equipment has been designed and developed to generate output consumables. The value chains illustrate a lower reliance on consumables moving forward and subsequently demonstrate an emerging dominant play in digital equipment.

Chapter 6 introduces several sourcing frameworks. Comprehensive analysis utilizing Professor Fine's sourcing framework illustrates that image engine performance directly impacts the level of digital image quality; hence, strategic control of this module is critical in order to maintain firm competitive advantage. Additionally, some outsourcing case studies are provided.

Chapter 7 focuses on product platforms as a means to improve image engine performance requirements, reduce costs, and increase speed to market. In addition, this chapter provides an examination of organizational learning and the importance of product innovation as a means to ensure efficient and successful strategic planning. Case studies are included to illustrate firms that successfully implemented platforms.

Chapter 8 provides a synopsis of this work. It addresses the impact of this project in providing a baseline for an image engine platform.

CHAPTER TWO: STRATEGIC CORE COMPETENCE

2.0 Introduction

History has shown that some of the nation's top rated companies have had difficulty maintaining their competitive advantage. In 1994 a research study revisited and updated the ranking for those industrial firms considered to be the 100 largest firms in the United States as of 1980. In order to conduct this study, researchers followed these same 100 firms for twelve years until 1992. At this time only 56% of these firms were still in the top 100, and only 18% had improved their ranking. The study highlighted the fact that 82% declined in their performance and/or were eliminated from the ranks.[3] It can be concluded that 82% of these companies failed to maintain a dynamic corporate vision.

In maintaining a dynamic corporate vision, planning must be based on a continuous effort to identify emerging opportunities in the external environment. It is of utmost importance that firms continue to perform market research and are aware of current and future market demands. Appropriate market analysis will ensure that firms identify potential growth opportunities. New growth opportunities can embody two forms – either continuous product improvement or disruptive technology. Continuous product improvement will fit buyers' needs, making product changes as required, maximizing product quality, and/or increasing product features. Disruptive technology most often offers buyers a substitute product that replaces current product market offerings. Identifying potential market opportunities is the first step that a company must take to ensure a dynamic corporate vision.

The second step to maintaining a dynamic vision involves the ability to plan, continuously improve, and implement further core competency development. Core competencies are a set of differentiated skills, complementary assets and routines that provide the foundation for a firm's sustainable competitive advantage.[4] In a learning organization, this knowledge is retained within a group of highly skilled professionals who continuously work to enhance and grow the current core competencies. These core competencies in turn serve in providing a springboard for new business development.

The third step in maintaining a dynamic corporate vision involves creating a center of excellence for competency development and renewal. Centers of excellence provide a platform

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[3] Long, C. and Vickers-Koch, M., "Using Core Capabilities to Create Competitive Advantage," Organizational Dynamics, vol. 24, no. 1, 1995, pp. 6-23.

[4] Leonard-Barton, D., "Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development," Strategic Management Journal, vol. 13, no. 2, 1992.

from which to leverage resources to other programs without additional time and cost penalties. The design and implementation for a competency center of excellence is reliant on the success of a corporate-wide competency initiative to obtain buy-in from each line of business.

2.1 Strategic Product Planning

> *"Rather, we will see the greatest rewards go to the companies that can anticipate, time after time, which capabilities are worth investing in and which should be outsourced; which should be cultivated and which should be discarded; which will be the levers of value chain control and which will be controlled by others."*[5]

Professor Charles Fine in his book *Clockspeed* underscores the importance of maintaining a corporate dynamic vision and the critical role of strategic product planning. As pointed out earlier a firm must first understand the external environment and future market demand. Once the external market is clearly understood, a firm can begin to discriminate among those competencies that have become core rigidities and those that require further development. Further they can begin to identify areas those areas which will require new competency development. In addition, value chain mapping will enable firms to determine subsequent product/subassembly sourcing strategies. This in turn is an essential component in allowing a firm to maintain competitive advantage.

The strategic development process places primary importance on the firm's ability to meet customer and stakeholder needs. The following steps are critical for successful strategic planning:

1. Establish a future corporate vision that defines and gives meaning to the organization's strategic purpose.
2. Assess past capabilities and determine the current core competencies the company has depended on and leveraged to create value.
3. Identify capabilities that have potential to become core rigidities.
4. Explore new core competency needs and examine methods for enhancing core competencies that need further development.
5. Identify new product opportunities among the company's current customers and market segments.
6. Develop an appropriate resource allocation plan and set appropriate deadlines to ensure product commercialization efforts occur within allocated time frame.

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[5] Fine, C., Clockspeed: Winning Industry Control in the Age of Temporary Advantage, Reading, MA: Perseus Books, 1998.

Recognizing and acting on the steps required for successful strategic planning will ensure that a firm is positioned to rapidly respond to market changes and meet customer demands.

My work at Eastman Kodak focused on steps 2 and 3 in the strategic planning process. A significant portion of my time was dedicating to assessing the current manufacturing high-end digital equipment core competencies. The value chains were mapped for each line of business in order to understand the significance of these manufacturing core competencies in creating firm value. In addition, the role of these core competencies in relation to the corporate vision was analyzed. Once the value chains were defined new competency needs were then determined.

2.1.1 Strategic Control Measures

Strategic control measures will guarantee successful implementation of planning efforts. A strategically controlled firm environment is based on (a) corporate culture, (b) technological knowledge, and (c) successful alignment of motivational effort. Without strategic control measures, implementation efforts can be stifled as a result of deeply embedded managerial routines, incentive systems, and firm values.

Corporate culture is a critical strategic control measure serving to shape firm values and influence intrinsic motivation and behavior. Changes in firm culture have potentially far greater long-term effects than changes in externally imposed controls. In order for a firm to grow and develop future core competencies, an organizational culture must be one in which the appropriate organizational structures are in place for knowledge sharing to occur. The following quote demonstrates a cultural model where innovation and knowledge sharing are encouraged.

> *"The culture would promote a vision of the corporation as an internal market-place of ideas, skills, technologies, experience, and knowledge, in which the traders are those who embody and carry core competencies, and the customers are senior managers, responsible for guiding the process of building competencies to ensure sustainable success."*[6]

This cultural model requires a significant transitional shift from a rigid organizational product structure. Rather than analyze the organization as a conglomerate of dissociated units, successful strategic thinking examines the organization as a holistic system where all parts are viewed as integral in relation to the whole system.[7]

A significant shift in corporate culture will require a new corporate vision. In order to change firm culture and encourage knowledge sharing between the lines of business, the new corporate

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[6] Band, C. and Scanlan, G., "Strategic Control through Core Competencies," Long Range Planning, vol.28, no.2, 1995, pp. 102-114.

[7] Bonn, I., "Developing Strategic Thinking as a Core Competency," Management Decision, vol. 39, no. 1, 2001, pp. 63-71.

vision must first be communicated. This strategic vision when communicated throughout an organization by top management will confirm the importance of core competency growth and corporate-wide knowledge sharing. Without the appropriate structures and processes to foster continuous exchange across the departments and among upper-management, employee expertise and creativity will not be best utilized.[8]

Technological knowledge is considered the second strategic control measure. Strategic planning is heavily reliant on the technological skills to understand the current and/or future market needs. Further, specific technological resources and skill sets are required to define future product requirements, develop future competencies, and assess product integration efforts. A firm will not be able to efficiently plan and maintain competitive advantage without the appropriate internal technological knowledge. This knowledge is most often centered within a group of highly talented employees. Therefore, a focus on both recruiting and retaining the appropriate people to develop and grow future core competencies is essential.

Motivational efforts are the last critical strategic control measure. Appropriately aligned motivational efforts are essential in order to implement and carry out strategic planning initiatives. Managerial routines, incentive systems, and firm values will all serve in shaping motivational efforts. The creation of new incentive structures to motivate and reward positive employee behavior will help to align motivational efforts with new strategic plans. If these routines, systems and values are not aligned to appropriately motivate efforts, the strategic planning initiatives will result in failure.

Control measures provide a support structure in which to monitor and improve current planning efforts. These control measures will help to ensure the firm is constantly integrating and analyzing its strengths, weaknesses, and market opportunities. Models such as Porter's 5 Forces described in Section 2.3 provide a model by which to assess firm competitive advantage.

2.1.2 Strategic Planning Group

"Vision shared throughout the organization fosters commitment rather than compliance and creates a sense of commonality that permeates the whole organization."[9]

A strategic planning group at the corporate level is a critical factor in encouraging communication between the lines of business. More importantly this group is positioned to create and 'permeate' a shared corporate vision. With members representing the various business units

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[8] David C. Band and Gerald Scanlan, "Strategic Control through Core Competencies," Long Range Planning, vol.28, no.2, 1995, pp. 102-114.

[9] Bonn, I., "Developing Strategic Thinking as a Core Competency," Management Decision, vol. 39, no. 1, 2001, pp. 63-71.

across the firm, this group is able to support and promote knowledge sharing among the units while at the same time attempting to reduce organizational boundaries.

A strategic planning group provides the infrastructure with which to develop and implement core competency planning and monitoring of future growth. Through focusing on organizational restructuring efforts, future market segments, incentive structures, firm culture and transformational change, the strategic planning group provides a solid basis in which to maintain competitive edge in a rapidly changing marketplace.

A strong strategic planning group will have major implications for a firm's employees. Aligning appropriate incentive structures with the appropriate implementation of the corporate vision will provide motivation for employees to leverage their knowledge and skills to accomplish their individual goals.

2.1.3 Implications of Strategic Planning on Acquisition Strategy

Strategic planning directly impacts corporate acquisition strategy. First the examination and analysis of current and future core competencies enable an organization to recognize the importance of their competencies and/or capabilities as strategic resources. Empowered with this new insight a firm can assess the external market demands to further enhance and/or develop new competencies to match market changes. Core competency development may involve joint ventures, license agreements and/or acquisitions.

In addition, value chain mapping will illustrate where firm value is currently created. Strategic market analysis on potential upstream and/or downstream value chain integration will serve as a guide in determining appropriate market play and future acquisition strategy. Chapter five will provide a detailed analysis of Kodak's value chain maps.

In years past firms often searched for more direct and rapid methods for affecting share price. For example, firms would assess which markets were growing given the forecasts for future change and then proceed to acquire companies in this new market segment. History has shown that without strategic planning, the latter acquisition method can lead to further declines in annual operating profit.[10]

2.2 Innovation

In order to ensure competitive market advantage, companies are reexamining their portfolios to assess how to better utilize their core competencies to create sustainable value. Firms can no

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[10] Long, C. and Vickers-Koch, M., "Using Core Capabilities to Create Competitive Advantage," Organizational Dynamics, vol. 24, no. 1, 1995, pp. 6-23.

longer measure success based solely on market share growth. The rapid pace of technological change has led firms to create new businesses. Oftentimes these new segments are disruptive technologies or innovations that hold potential to make a product line or entire business segment obsolete. Organizations that fail to discriminate the early warning signs of technical discontinuity in the environment may struggle for survival if they wait too long to develop a new business strategy. Nadler and Tushman in their article *Organizational Learning as the Creation of Corporate Competence* highlight some strategic imperatives for successful firm innovation.[11]

- Firms must engage in both incremental and discontinuous technical change.
- Firms can not succeed with a 'one-size fits all' approach to the marketplace.
- The ability to rapidly implement new strategies and successfully commercialize product is a source of competitive differentiation.
- Careful monitoring of industry outliers and minor players is crucial - oftentimes these groups are the first to develop new technologies and alter conventional product designs.

Failure to develop and enhance current core competencies will result in the inability to capitalize on emerging market growth opportunities. As stated earlier, without current firm competency development the technological knowledge and required skill sets will be absent from firm resources. Thereby, these firms will no longer have the ability to respond to market demand for internally designing and developing future products. (This includes design and development for both incremental and discontinuous products). Rebuilding the appropriate competency infrastructure would prove a high cost and time consuming process that in a rapid clockspeed environment would result in loss of competitive advantage.

Upper management faces a difficult paradox – weak strategic control measures can encourage employee complacency and lack of firm direction, while strong strategic control measures can stifle employee innovation. An example of a company that recognized this difficult paradox is 3M. The company implemented the "15% rule", which was developed to foster innovation by allowing technical employees to spend up to 15% of their time on self-selected innovative projects.[12]

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[11] Dunphy, D., Turner, D., and Crawford, M., "Organizational Learning as the Creation of Core Competencies," Journal of Management Development, vol. 16, no. 4, 1997, pp.232-245.

[12] Bonn, I., "Developing Strategic Thinking as a Core Competency," Management Decision, vol. 39, no. 1, 2001, pp. 63-71.

2.3 Assessing Firm Competitive Advantage through Porter's Five Forces

Porter's five forces provide a model to assess a firm's competitive advantage.[13] The model offers a detailed framework for examining both current and/or future core competency maintenance as well as further competency development. In Chapter 5, this model will be used to analyze the value chain maps developed for each line of business.

The model includes the following forces: (1) threat of entry, (2) rivals, (3) substitutes, (4) buyer power, and (5) supplier power. Each force is highlighted below; the significant parameters for each force that should be considered are also listed.

1. *Threat of Entry*: Threat of entry refers to entrance into the market by new players. The threat of entry can be categorized as low if newcomers can expect sharp retaliation from entrenched competitors. The parameters listed below should be carefully assessed in order to determine the magnitude for threat of entry.
    A *Economies of Scale*: Economies of scale occur when the unit cost of a product declines as the absolute volume increases. Economies of scale can deter entry by forcing the entrant to come in at a large scale and risk retribution from existing firms.
    B *Capital Requirements*: Capital requirements can deter entry due to the need to make large financial investments up front.
    C *Product Differentiation*: Established firms have brand identification and customer loyalties.
    D *Switching Costs*: One-time buyer cost for switching from one supplier's product to another.
    E *Access to Distribution Channels*: New entrants must secure distribution channels.
    F *Cost Disadvantages*: Disadvantages independent of economies of scale can include favorable access to raw materials and learning curves.
2. *Rivals*: Competition between rivals can weaken the firm's ability to increase profit margins.
3. *Substitutes*: The level to which the firm can raise prices before buyers prefer substitute products.
4. *Buyer Power*: Buyer power can vary depending on the following conditions.
    A. When the product represents a significant fraction of buyer costs, buyers are more likely to purchase selectively.

B. Buyers have the option to select alternative suppliers if the product is undifferentiated or a standard product.
C. Low switching costs enable buyers to select alternative suppliers.
D. The buyer group has the capability to backward integrate, thereby controlling larger segments of the value chain.
E. Buyers have access to 'full information', which serves to ensure favorable prices.

5. *Supplier Power*: Supplier power can vary depending on the following conditions.
   A. Small groups of suppliers are dominant in the market and sell to a more fragmented buyer group.
   B. Supplier groups have differentiated products.
   C. Supplier groups have high built-in switching costs that make it difficult for buyers to select an alternative supplier.
   D. Supplier groups have the capability to forward integrate and thereby control larger segments of the value chain.

The diagram below illustrates Porter's five forces. Each of the forces is represented in the diagram; it should be noted that the magnitude of the arrows is in no way representative of any real life analysis. Rather the arrows serve to illustrate the effect on price and/or cost from each force. Therefore it is shown that the threat of entry, rivalry, substitution, and/or buyer power serve to lower product price, while supplier power and/or rivalry serve to increase product cost. The profit margin is then a result of subtracting the product cost from the product retail price.

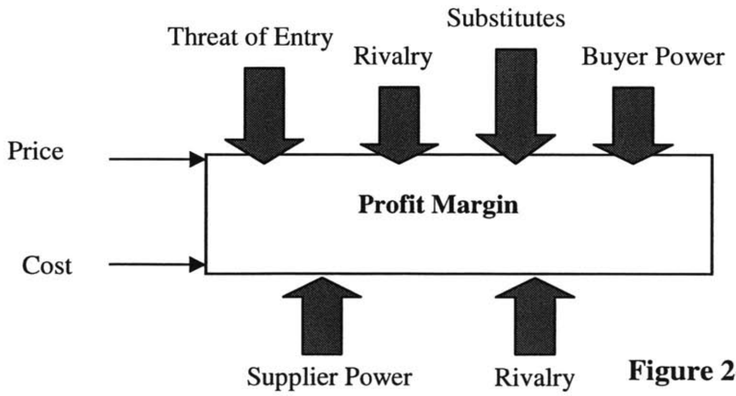

Figure 2-1: Porter's Five Forces[14]

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[13] Sorensen, J., Lecture Notes: 15.900 Strategic Management, MIT, Fall 2002.
[14] Sorensen, J., Lecture Notes: 15.900 Strategic Management, MIT, Fall 2002.

This model will serve in determining the degree of product competitive advantage. Products that result in a high degree of firm competitive advantage can then be assessed for strategic core competency development. The next step is to determine the core competencies that need to be maintained, enhanced and further developed in order to maintain product competitive advantage.

2.4 Core Rigidities

Core competencies are the capabilities that are fundamental to a firm's performance. Firm-wide capabilities that serve to define and shape a core competency can also work to constrain firm development. When deeply entrenched firm core competencies are applied to develop nontraditional products that require new capabilities, these core competencies can turn into core rigidities. There are four measures that serve to define firm capability and enhance core competencies; these measurements can also serve to solidify core rigidities.[15] They are listed below in the order of weak to strong potential for becoming a firm's core rigidity:

1. *Technical Expertise*: There is a high probability that technical expertise for specific systems is held by a select number of employees within a department. Changing a group of employees' expertise is feasible; however, this will require the necessary funding and time for employee training.
2. *Organizational Routines*: These organizational structures usually extend across departments. They require acceptance by all individuals across groups and therefore are more difficult and resistant to change.
3. *Incentive Systems*: Incentive systems are deeply embedded within a firm culture and are built over long periods of time; they are therefore far more arduous to alter.
4. *Values*: Intangible resources such as corporate culture and brand name implicitly shape firm values. The process of changing a culture is an extremely slow and difficult one.

Technology organizations must remain diligent in challenging their current standards. While the measurements listed above can help to foster corporate-wide acceptance for achieving sustainable competitive advantage, they can also create an 'organizational inertia' that can limit an organization's ability to discern new signals from the environment and take appropriate action.[16] The rapidly changing external environment makes it absolutely critical that organizations develop

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[15] Leonard-Barton, D., "Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development," Strategic Management Journal, vol. 13, no. 2, 1992.

[16] Hafeex, K., Zhang, Y., and Malak, N., "Core Competence for Sustainable Competitive Advantage: A Structured Methodology for Identifying Core Competence," IEEE, vol. 49, no. 1, 2002, pp. 28-35.

new core competencies and enhance existing ones while ensuring that the current core is maintained sufficiently.

Eastman Kodak provides a classic example of a firm that until just recently has been deeply entrenched in core rigidities. While the digital equipment market has exploded the past few years, Kodak has been very slow in transitioning from the analog into the digital market segments. In fact, it was only in July of 2003 that Kodak announced the transition from film into the digital equipment segment. Why has the transition been such a lengthy one? The reasons for this lengthy transition period maybe well explained by the factors listed above. Kodak's values and brand name have always been associated with film. Transforming an entire corporation from a focus on consumables to one centered on digital equipment is by no means an easy process. This process of change is a difficult and extremely complex task.

In addition, the focus on output consumables has had major implications for Kodak employee motivation and incentive systems. Traditionally, these systems have been based on the development, design and manufacturing required to generate output consumables, such as film and silver halide paper. The shift away from the consumables has far reaching implications for motivation and incentive systems. The incentive systems must be realigned to incorporate the new corporate vision which embodies a digital equipment focus.

Older organizational routines or structures must change to align with the new vision. For example, allocation of funding and sourcing strategies will be impacted. The structures to maintain and enhance these core competencies must be redesigned and implemented. Lastly, technical expertise will shift from a focus in silver halide and film technology to digital equipment.

2.5 Corporate-Wide Core Competency Initiative

"Core Competence is communication, involvement, and a deep commitment to working across organizational boundaries."[17]

A corporate-wide core competency initiative can provide a framework to change organizational routines and employee incentives to better realign with a new corporate vision. If implemented appropriately the initiative can serve to direct core competency development and future competency needs; thereby acting as a strategic control measure to prevent core rigidities. Core competencies should be leveraged across lines of business. Knowledge sharing between the

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[17] Prahalad, C.K. and Hamel, G., "The Core Competence of the Corporation," Harvard Business Review, vol. 68, no. 3, 1990, pp. 79-92.

lines of business is critical in order to efficiently create, enhance and further develop corporate-wide core competencies.

While physical assets will depreciate with time, core competencies will grow as they are shared across business units. To gain world leadership upper management must understand and develop a sustainable competitive strategy at both the business unit and corporate levels. The following quote summarizes the importance of corporate-wide competencies.

> *"The real source of advantages are to be found in management's ability to consolidate corporate wide technologies and production skills into competencies that empower individual businesses to adapt quickly to changing opportunities."*[18]

In order to 'consolidate' core competency technologies and future development efforts, top-management must lead the efforts. The corporate-wide initiative will serve to first convey the new corporate vision. More importantly, the initiative must work to achieve buy-in from each line of business. Without buy-in from each business unit the initiative will never accomplish its objectives. Once buy-in is achieved, the lines of business can jointly work to bridge the competency gaps; corporate-wide renewal efforts will result in lower development funding expenditures for each line of business.

2.5.1 Kodak: Requisite for Corporate-Wide Competency Initiative

Analysis of Eastman Kodak today will illustrate a highly decentralized organization. The firm is divided into multiple business units, with each unit solely focused on the success of their individual product portfolios. Research has demonstrated that capability based organizations place significant effort in defining innovative processes for applying their core capabilities across the lines of business.[19] At Kodak, knowledge sharing of best practices across the lines of business is currently minimal, resulting in less than optimized core competency maintenance and development. Chapter 3 provides a detailed analysis of the digital equipment manufacturing core competencies that are shared across the lines of business. While these core competencies are shared across the units, the lines of business would prefer to 'control' the assembly and competency development process internally, rather than utilize a center of excellence.

The lines of business have become increasingly insular as a result of numerous reorganizations, budget cuts, and layoffs. Long-term strategic planning has consequently been

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[18] Prahalad, C.K. and Hamel, G., "The Core Competence of the Corporation," Harvard Business Review, vol. 68, no. 3, 1990, pp. 79-92.

replaced by short-term survival mentality. As a result, the primary metric for measuring business unit performance has been short-term quarterly profit gain. This fixation on stock price and the internal competition between business units results in several undesirable outcomes. First, the business units are in deep competition with one another for firm resources such as R&D investment. Second, upper management spends a great deal of planning time on allocating financial resources and portfolio balancing, with little expended toward growing the firm as a whole, while examining synergy between business units.

One vital factor that oftentimes prevents corporations from investing resources into core competency development is that reshaping competencies doesn't provide immediate business impact. Further, the expected benefit can often be difficult to accurately quantify. It is critical to note that results from work in development and strategic planning of core competencies will have dramatic firm impact over time.[20]

The implementation of a corporate-wide core competency initiative to foster communication between the lines of business is essential. The initiative can serve to monitor core competency development and future competency needs. This framework will therefore serve as a strategic control measure to foster core competency development and renewal.

2.6 Outsourcing

Western companies typically measure firm competitiveness according to the resulting product price. All efforts are placed on driving cost down, which often correlates to outsourcing everything from IT and software development to manufacturing. As a result, the firmly established core competency skills critical for next generation planning are significantly diminished. While outsourcing can lower cost, it does not necessarily aid in enhancing the knowledge base critical for future product leadership. Additionally, manufacturing internally can enable a firm to directly receive customer feedback which in turn provides a critical metric on which to base changes and enhancements in current core competencies. Loss of the ability to monitor and control internal competencies will make it difficult to enter emerging markets. Those firms dependent on their suppliers for knowledge will be forced to serve solely as the distribution channel in the value chain.

Honda provides an example of a firm that is strategically focused on maintaining and further developing their core competencies in small engines. The firm designs and manufactures all of

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[19] Long, C. and Vickers-Koch, M., "Using Core Capabilities to Create Competitive Advantage," Organizational Dynamics, vol. 24, no. 1, 1995, pp. 6-23.

[20] Dunphy, D., Turner, D., and Crawford, M., "Organizational Learning as the Creation of Core Competencies," Journal of Management Development, vol. 16, no. 4, 1997, pp. 232-245.

the key parts and equipment that the engines encompass. For the functions with which Honda is less than 'best-in-world' they opt to outsource.[21] Traditionally Japanese firms have made strategic alliances with western companies to enhance their internal core competencies. While western partners were not committed to keeping competencies in-house, Japanese companies leveraged these to enhance their opportunities for internal competency development.

A corporation can potentially enhance their competitive advantage through an alliance that emphasizes the commitment of resources. Prahalad and Hamel define these resources as the following: (1) Commitment to travel, (2) Group of dedicated employees, (3) Pilot facilities, and (4) Time to reflect on lessons learned.[22] The commitment of resources in turn can help to shape and develop corporate learning.

2.7 Product Platforms

Failure to invest in development and manufacturing competencies necessary for sustainable competitive advantage will stifle growth and potentially lead to corporate demise. In high capability firms core competencies most often extend outside single product families, and have a longer lifecycle. Product platforms are one method to facilitate more rapid product development for specific product variations. Utterback coined the phrase "speed-management" in referring to the adoption of product platforms. Utterback states, "Planned renewal of product platforms combined with sustained development of core capabilities is a defense against technological surprises and obsolescene."[23]

When the organization is comprised of several lines of business that are all competing for resources, there is little incentive for maintaining and enhancing corporate core competencies across units. In addition, large reengineering work occurs during product design and development. Product platforms provide a framework to assure competency renewal, together with reducing the amount of product reengineering. Therefore platforms provide a methodology in which to lower product cost and increase product profitability.

The results of this project provided the baseline for an image engine platform at Eastman Kodak. Platforms offer a methodology by which to improve product performance requirements, reduce image engine costs and increase speed to market. Implementation of product platforms

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[21] Quinn, J. "Strategic Outsourcing: Leveraging Knowledge Capabilities," Sloan Management Review, vol. 40, no 4, 1999, pp. 9-22.
[22] Prahalad, C.K. and Hamel, G., "The Core Competence of the Corporation," Harvard Business Review, vol. 68, no 3, 1990, pp. 79-92.
[23] Meyer, M. and Utterback, J., "The Product Family and the Dynamics of Core Capability," Sloan Management Review, vol. 34, no. 3, 1993, pp. 29-48.

requires thorough examination of the end-to-end commercialization process. The focus of Chapter 7 is on the importance and implementation of platforms.

2.8 Summary

In a learning organization, learning is a managed process and a top priority for upper-management. The enhancement and creation of future core competencies is the key characteristic of the learning organization. In this type of organization, the firm has developed effective competencies for monitoring industry forces. As a result the firm is able to plan, continuously improve, and implement a viable corporate business strategy to further core competency development.

In the traditional management model, firm managers focus on 'bottom-line' performance shaped by existing business units and end products. "Rather than thinking of the company as a portfolio of businesses, managers must recognize the company as a portfolio of competencies."[24] Corporate leadership will help in fostering buy-in from each line of business for a corporate-wide core competency initiative. Once the units assume ownership for competency renewal efforts, closure of the competency gaps can begin to be filled. Corporate-wide competency renewal efforts will result in lower development funding expenditures for each line of business.

We often examine a firm strictly in terms of its end products. With conscientious practice, however, we can begin analyzing the core competencies that enabled the successful development for these end products. An alternative explanation for core competencies provides a powerful framework to the firm as a tree.[25] In this metaphor the roots symbolize core competencies that enable the firm to sustain its existing branches and grow new ones. The trunk represents core products that support the lines of business and are placed into end products. For Kodak, the trunk represents image engines or the optomechatronic readers and writers that are placed in printers, cameras, and scanners. The branches denote the lines of business reaching ever outward.

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[24] Deavers, K., "Outsourcing: A Corporate Competitiveness Strategy, Not a Search for Low Wages," Journal of Labor Research, vol. 18, no. 4, 1997, pp. 503-519.

[25] Shoemaker, P., "How to Link Strategic Vision to Core Capabilities," Sloan Management Review, vol. 34, no. 1, 1992, pp. 67-82.

CHAPTER THREE: MANUFACTURING CORE COMPETENCIES

3.0 Introduction

The current core competencies and respective capabilities within Division A were thoroughly assessed. The core competencies determined were as follows: (1) Submicron alignment of optical and mechanical systems, (2) Image system optimization, and (3) Image quality test and verification. These core competencies are leveraged across Kodak's Lines of Business in a wide variety of products. This chapter describes each of the core competencies and respective capabilities.

3.1 Core Competency: Sub-micron Alignment of Optical and Mechanical Systems

The first core competency is the sub-micron alignment of both optical and mechanical systems. The capabilities or enablers that encompass this core competency include the following: (1) Automated Precision Imager Alignment, (2) UV Precision Adhesive Characterization, (3) Laser Alignment, (4) Optical Positioning Metrology, (5) MEMS LED Alignment and (6) Precision Laser Launch into Single Mode Fibers.

3.1.1 Automated Precision Imager Alignment

The automated precision imager alignment utilizes automated active alignment fixtures. These fixtures have multiple design configurations for use in both area and linear array technology. This competency is utilized for capture devices such as the high-end cameras (i.e. Pro14n and Digital Camera Backs), and the high-end scanners (i3500 or i800 series). The area array imager alignment exemplifies a critical process required for manufacturing high-end cameras. The linear area array imager alignment exemplifies a critical process required for manufacturing the high-end scanners. Section 3.1.1.1 addresses the area imager array while section 3.1.1.2 illustrates the linear imager array active alignment.

3.1.1.1 Area Imager Array Active Alignment

The purpose of the Flexible Robotic Assembly Metrology (FRAM) fixture is to align the subassemblies to the required specification tolerances before placement into final product. For example, for the Digital Camera Pro14n the FRAM is utilized to automatically align the imager chip (an active area array), onto a metal plate that is placed directly into the camera body. If the imager chip (area array) is not aligned to the metal plate correctly, both the focus and magnification of the camera will be of poor quality. The diagram below illustrates the placement of the imager chip to the metal plate.

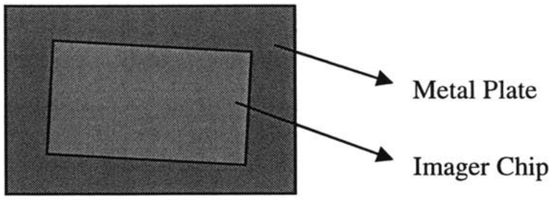

Figure 3-1: Imager & Plate Alignment

For products with an area array, the FRAM aligns the subassembly according to six-axis positioning (1) x-axis, (2) y-axis, (3) z-axis, (4) tilt x, (5) tilt y, and (6) rotation z. Figure 3-2 illustrates these positions:

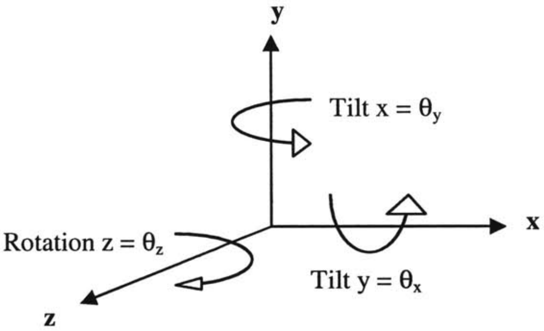

Figure 3-2: Six-Axis Positioning

For high-end cameras, once the metal plate is placed into the camera the critical components of the camera are all fixed relative to the metal plate. The rational for the FRAM, is that the area array die placements on the imager chip, obtained from the manufacturer, are all slightly misaligned. Therefore, because of this possible misalignment in any or all of the six-axis, the positioning specifications of the imager chip onto the plate varies from plate to plate. The alignment fixture has the capability of projecting a target image onto the area array; when the imager chip is aligned appropriately the area array digital bits will exactly match the known target bits. The Kodak proprietary software utilizes a series of algorithms to measure and correct for alignment (center x, center y, center z, tilt x, tilt y), focus (rotation z) and magnification. This is performed, by driving the controller with error signals that are given as output from the propriety software.

The FRAM has the capability to align area arrays ranging from 1.5Megapixels to 12Megapixels. The diagram below illustrates the FRAM process for aligning the imager for the Pro14n camera to match the target specification.

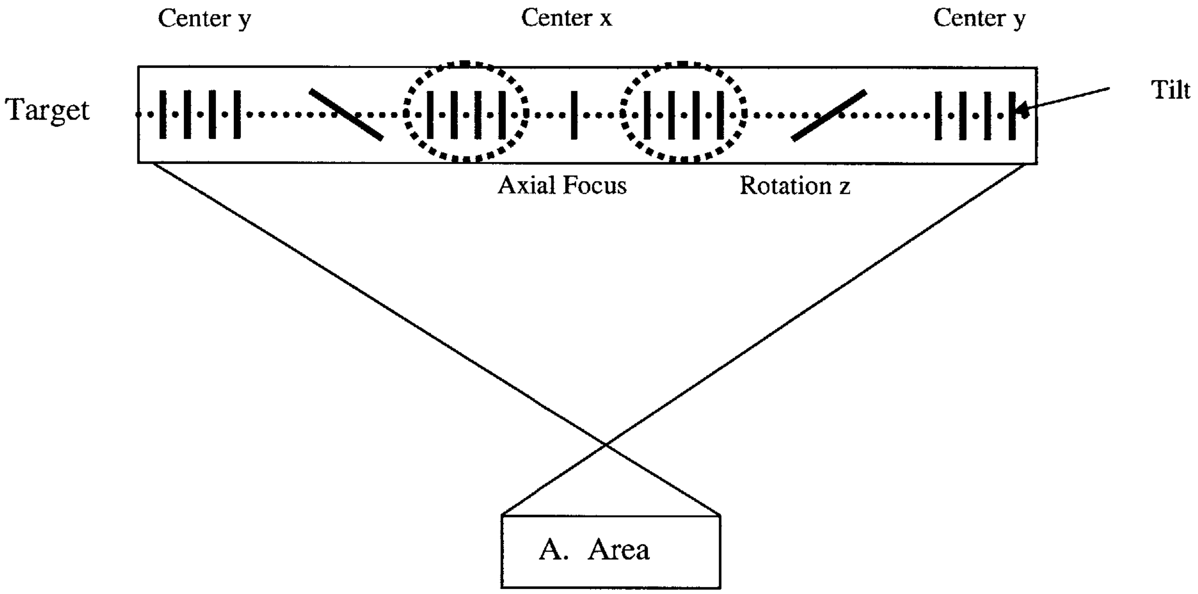

Figure 3-3: Area Array Alignment to Target Specification

The Modulation Transfer Function is used to determine tilt and magnification. The MTF data generated for all of the iterations include the values: M_y (less than center y), P_y (greater than center y), Axis, M_x (less than center x), P_x (greater than center x). When all of the axes are aligned, the software will stop the iteration, completing the alignment process.

3.1.1.2 Linear Imager Area Active Alignment

The FRAM also has the capability to automatically align linear arrays. The process for the linear imager array is very similar to the area imager area, however; the FRAM aligns the array for five axes positioning rather than six. Linear arrays are found in products such as film and paper. A linear array captures a dynamic image rather than a static image (i.e. Digital Pro14n camera). Linear arrays are one-dimensional arrays, in which the alignment process converts one-channel displays to four channels. These channels include red, blue, green and a detail channel.

A diagram of the HR500 subassembly that fits into the i3500 series high-end scanner is illustrated below.

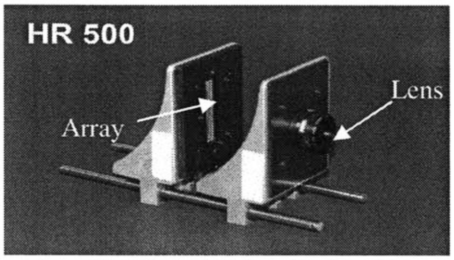

Figure 3-4: Application High-End Scanner[26]

3.1.2 UV Precision Adhesive Characterization

Adhesive precision characterization is a process in which the active alignment of the subassembly is 'locked into place'. This process of 'locking the alignment into place' is achieved with UV tack.

Once the subassembly has been appropriately aligned, the tool applies the ultra-violet radiation to specific locations. The diagram below illustrates the tool applying the UV radiation to the subassembly. This process is automatic in all systems except for the older generation products such as the HR500+ scanner. In this latter case, the technician manually adjusts the alignment to apply the UV radiation.

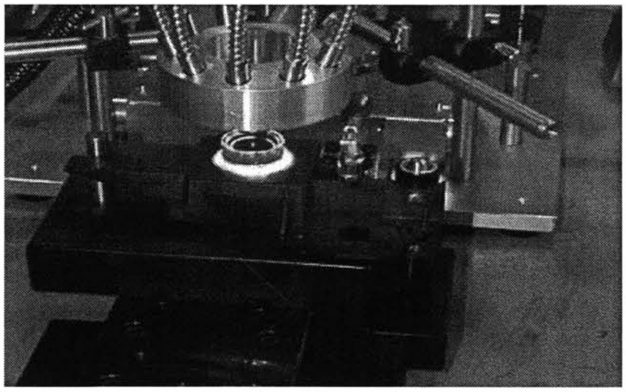

Figure 3-5: Adhesive Process[27]

The adhesive process can create shifts in the alignment of the subassembly. To account for this potential shifting, the system then runs another check to ensure the alignment hasn't shifted after the tool has applied the UV adhesive. After assembly of the first product batch, the

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[26] Image Courtesy of Kodak
[27] Image Courtesy of Kodak

mechanical shifts resulting from the adhesive placement and UV exposure can be accurately predicted. Once these shifts have been predicted the adhesive can be applied in a manner to compensate for the predicted shifts.

3.1.3 Laser Alignment

This capability manipulates laser light to meet product specification for uniformity, spot size, placement and angle. The figure below provides an example of a generic laser writer. The laser light beam is directed at the polygon mirror. This mirror continuously rotates in a full 360-degree circular motion, reflecting the laser light through a series of focusing lenses onto the mirror. The focusing lenses can involve very complex design, in order to appropriately shape the uniformity, spot size and angle to customer specifications. The polygon mirror deflects the laser light beam in a straight line across the entire mirror face – the light is consequently reflected onto the rotating drum writing line by line (one pixel at a time). This process transforms the beam from a static source of light into a moving light source. The accuracy of the polygon mirror is critical in order that the laser beam angle meet specification. Lastly, the drum rotates onto the toner, which then prints the image onto the paper.

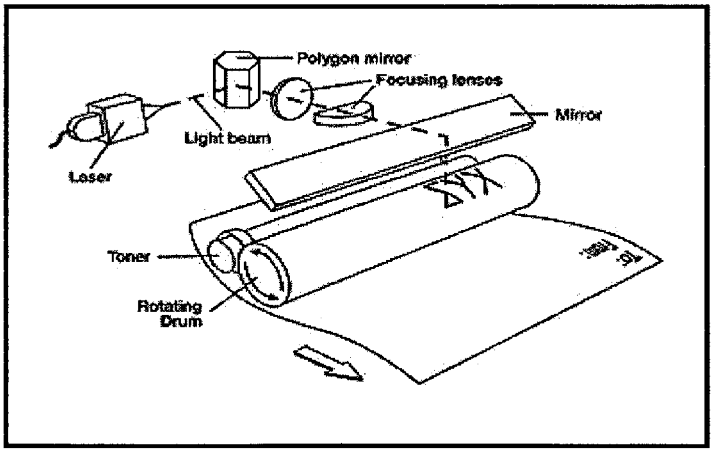

Figure 3-6: Laser Writer[28]

An example of this capability can be illustrated by examining the Laser-Marking Engine, the image engine for the 10K laser printer. The Laser-Marking Engine is used to scan an image and create a duplicate digital image. In this product laser light is manipulated in three key design areas: (1) the laser coupler, and (2) the shaper lenses. In the laser coupler design each individual

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[28] Image Adapted from www.OkiData.com

fiber (red, blue and green) is fiber coupled; the three fibers are then multiplexed to create an aligned white light. The competency found in this design is in usage of the AOM or Acoustic Optic Modulator. The AOM is used to adjust the spot size and power of the white light that is generated as output from the MUX. The placement of the shaper lenses is determined using a micrometer, and adjusted to appropriately meet the required uniformity, spot size, location, and angle. The picture illustrated below provides an illustration of laser spot size testing.

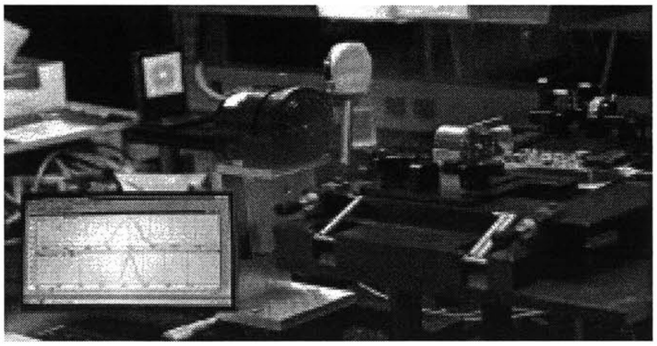

Figure 3-7: Laser Spot Size Testing[29]

3.1.4 Optical Positioning Metrology

The purpose for this competency is the ability to create specialized test fixtures to ensure that both the optical and mechanical subassemblies are appropriately aligned. There are a number of test fixtures that have been developed to support various products. These fixtures include the (1) Universal Polygon Test Fixture and (2) Optical Gauging Products (OGP) described in this section.

The Universal Polygon Test Fixture is used to test the polygons for reflectivity, jitter and pyramid angle. As highlighted above, polygons are a critical component for aligning laser beam light to meet specification. The software package generates a data file contained all of the parameters, which is used to determine whether the polygons meet specification.

The diagram below illustrates the complex test fixture that was designed.

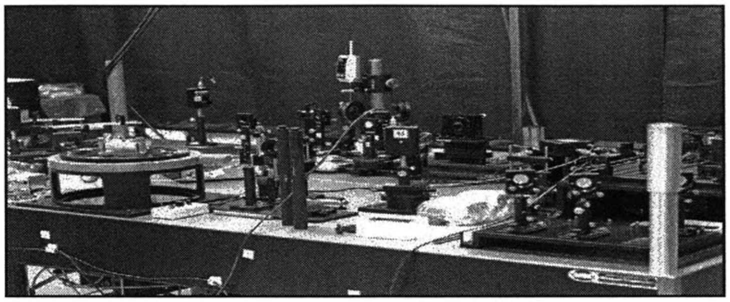

Figure 3-8: Universal Polygon Test Fixture[30]

The Optical Gauging Products (OGP) was purchased to test subassemblies, such as the LED printer head for Pegasus. OGP is a programmable scope that is utilized to take measurements at the micron level. OGP was used to ensure the appropriate placement of the LEDs for the Pegasus LED print head.

3.1.5 Precision Laser Launch into Single Mode Fibers

The purpose of this competency is the ability to manufacture optical fiber print head arrays. These print heads are precision assembled from quartz/glass fibers. The print head array is assembled from (1) fiber optic cables, (2) white light modules, and (3) an optics module. The 4 separate channels of the print head array are then tested for fiber transmission and variability and aperture transmission and variability. Lastly the fiber/aperture ratio is calculated to ensure the range is within specification.

3.1.6 MEMS LED Alignment

The function of this capability is the ability to align with the very high precision bare LED die into arrays on MEMS devices. This function is performed using the OGP (optical gauging product) described above in the Optical Positioning Metrology section 3.1.4. The LED Array Assembly shown in the diagram below was developed for use in printers. The assembly is placed around the rotor of the printer – its' function is to generate the scanned image. These die are first precisely aligned and then solder attached. The precision solder attachment is the most challenging piece of the design. This process is achieved while attaining uniform planarity of the light emission surface.

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[29] Image Courtesy of Kodak

[30] Image Courtesy of Kodak

It should be noted that each LED in the print head array is checked and verified to ensure that each aligns with the required tolerance. Each LED color from the 4 channels is graphed with respect to current and compared. Correlations are made to ensure that the channel LED colors are closely aligned.

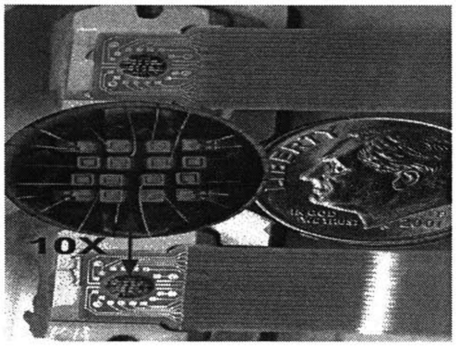

Figure 3-9: LED Precision Alignment[31]

The optical fiber print head array or Pegasus was designed to fit into the Kodak Professional RP 50 LED Printer. An example of a generic LED Array Printer is illustrated below.

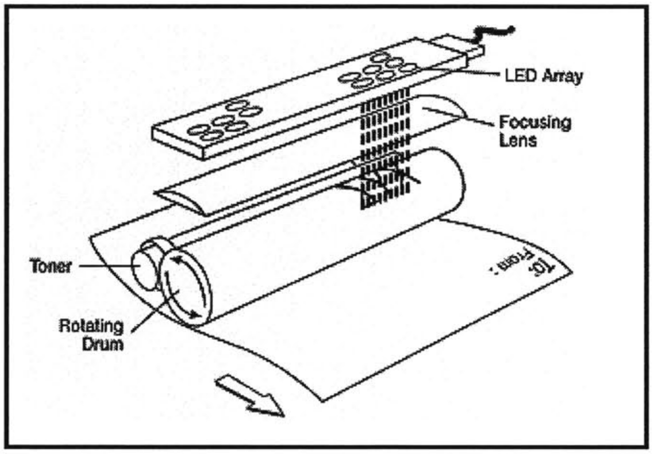

Figure 3-10: LED Printer[32]

To provide some background, thousands of individual solid state LED light sources together combine to form a linear array for the digital LED source. The source shines directly through focusing lenses onto the drum surface where the image is placed. The linear array stretches across the entire drum, which eliminates timing errors. Unlike the laser print head array, the LED print head array has no moving parts, which allows for higher speeds and resolutions. The LED print head offers a smaller dot size than the laser print head, therefore generating a higher image quality.

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[31] Image Courtesy of Kodak

[32] Image Adapted from www.OkiData.com

3.1.7 Further Analysis: Submicron Alignment of Optical and Mechanical Systems

The diagram below illustrates a free-body diagram of the submicron alignment competency. The inputs prior to alignment are listed on the right and resulting outputs parameters on the left. For example, given the alignment of a mechanical system such as for the Pro14 the following inputs would result: (a) imager Plate, (b) imager Array, (c) UV adhesives and (d) specifications. Both of the automated precision imager alignment and UV precision adhesive characterization core capabilities are required to align these inputs. The resulting outputs are (a) pixel location, (b) digital image quality and (c) MTF (Focus): X, Y, Z, tilt X, tilt Y, theta Z and magnification.

To highlight another example, given the alignment of an optical system such as for the laser marking engine the following inputs would result: (a) specifications, (b) polygon scanning mechanism and (c) RGB Laser. Three core capabilities are required to assemble the laser marking engine: (1) laser alignment, (2) optical positioning metrology (Universal polygon test fixture), and (3) precision laser launch into single fiber modes. The resulting outputs are (a) spot shape and size and (b) pointing.

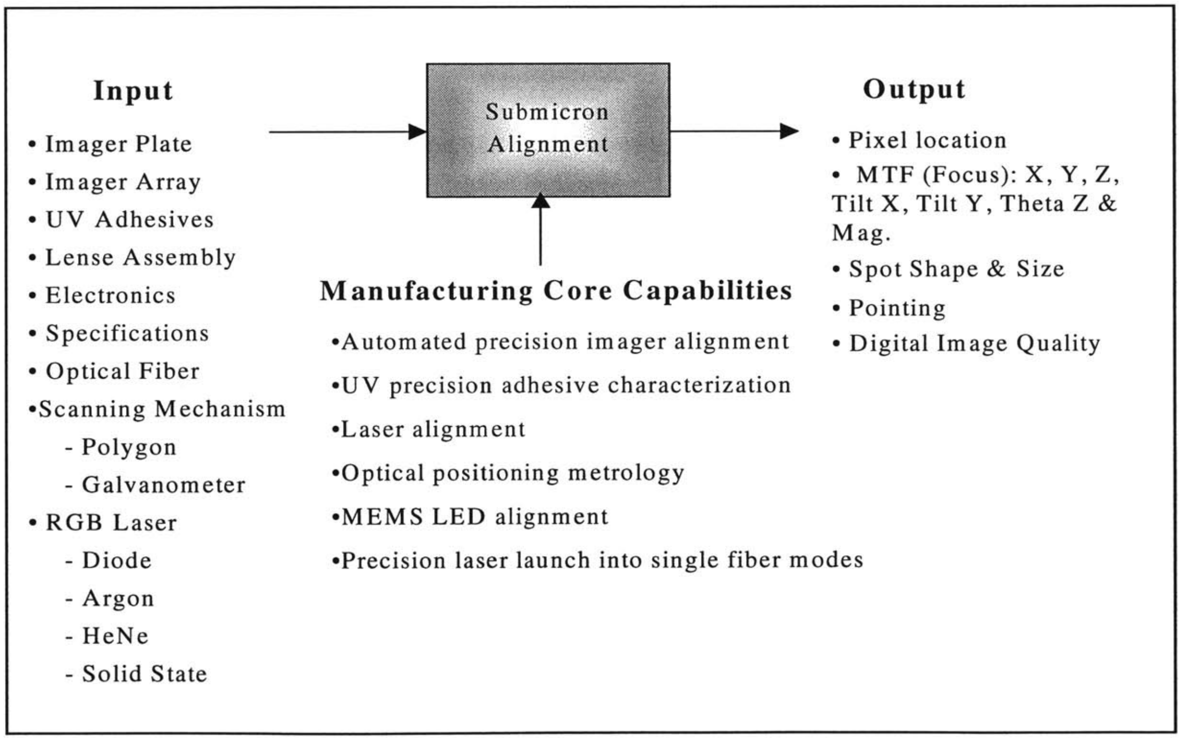

Figure 3-11: Submicron Alignment

3.2 Core Competency: Image System Optimization

This competency encompasses the ability to optimize image quality. The core capabilities or enablers that encompass this core competency include the following: (a) Laser illumination noise measurement, (b) Pixel uniformity mapping and (c) Color calibration.

Products containing RGB lasers are measured for laser illumination noise or energy distribution. This capability is described in much greater detail in section 4.3.

The integrating sphere test equipment developed by Kodak was developed in order to test pixel uniformity mapping and calibrate the imager quality. The raw images developed using both CCD and CMOS technology are tested using this technology. The parameters tested using the sphere include the following: TDA, column effects, column gains, linearity, tile gains, pixel gain, defect mapping, verification, and color. The tests are as follows:

- ☐ *Time Division Array*: The analog gain for each output analog imager channel is measured. The function of this test serves to equalize the gain response from the four channels.
- ☐ *Column gain and offset*: Calculates the normalized gain value and offset of the imager chip.
- ☐ *Linearity*: Maps out the linear coefficients to determine the response of the imager chip.
- ☐ *Tile Gains*: Compares groups of pixels (tiles) in the image to center.
- ☐ *Pixel Gains*: Each pixel in the image is compared to center.
- ☐ *Defect Mapping*: The columns, rows, pixels and clusters are mapped. A fixed number of gray color levels are subsequently analyzed for defects.
- ☐ *Verification test*: A number of parameters including green non-uniformity, noise, and dark tilt are tested and verified.
- ☐ *Color*: The calibration sphere is used to normalize the color performance to the design aim points. For each color, the output from the imager chip is compared to the calibration sphere. A feedback error correction factor is generated – resulting in an error correction matrix. The color chart below provides a generic example of the colors that would be generated by the calibration sphere for test and verification.

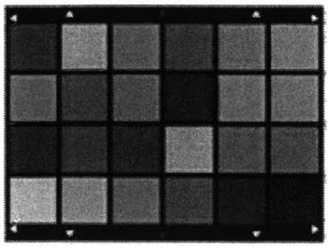

Figure 3-12: Generic Color Chart[33]

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[33] Image Adapted from http://www.tvcameramen.com/studio/utz02a.htm.

3.2.1 Further Analysis: Image System Optimization

The diagram below illustrates a free-body diagram of the image system optimization competency. The inputs prior to optimization are listed on the right and resulting output parameters on the left. For example, given the optimization for the Pro14n camera the imager array would serve as the input. Both the pixel uniformity mapping and color calibration core capabilities are required to optimize the imager array. The resulting outputs are (a) image quality artifact correction, (b) time division array, (c) column gain and offset, (d) linearity, (e) tile gains, (f) pixel gains, (g) verification test, and (e) color.

Highlighting the laser marking engine, the input in this product is the RGB laser. The core capability required is the laser illumination noise measurement. The output takes the form of an energy distribution with regards to both beam uniformity and MTF.

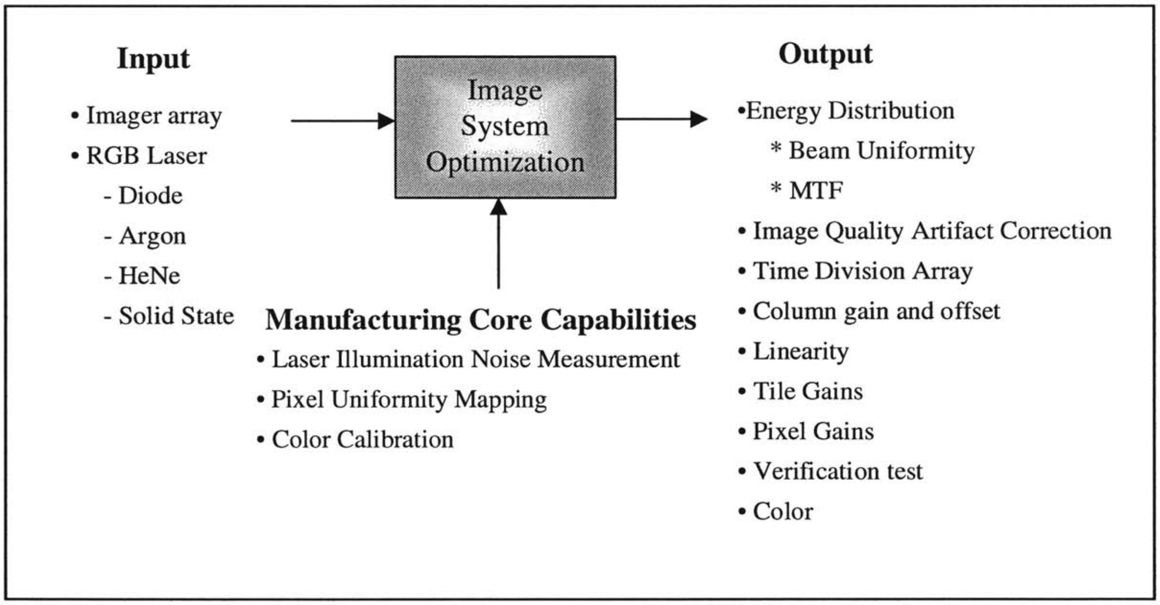

Figure 3-13: System Optimization

3.3 Core Competency: Image Quality Testing and Verification

This competency encompasses the ability to test and verify final image quality. The core capabilities or enablers that encompass this core competency include the following: (a) Quantified image quality analysis and (b) Qualitative image quality experts.

The digital image taken from final product is analyzed using either an image expert test stand and/or Maxwell's software algorithms. The digital image is assessed according to the following parameters:

- *Color calibration*: Testing the color chart for a given image.
- *Flair*: The amount of scattered light resulting from lens reflections or the subsystem interior; the scattered light will reduce the image contrast and detail.
- *PNI*: Pixel noise index – The ratio between the photo charge at a pixel and its respective output voltage.
- *PGI*: Pixel grain index – Method of defining 'graininess' in a photographic color print. In an area of overall uniform density, the measurement of the local-density variation ratio.
- *Banding Performance*: A print defect or artifact that can be characterized by a pattern of color/shading lines, rather than a uniform body of color.
- *Streaks*: Image deformity illustrated by a line or mark (differentiated by color or texture) from the surrounding image media.
- *Registration*: Image processing technique utilized to match a test image to a control image in order to assess for parameters such as distortion.

The second core capability encompasses the group of employees who are able to qualitatively assess the above parameters as another final check out test.

3.3.1 Further Analysis: Image Quality Test and Verification

The diagram below illustrates a free-body diagram of the image quality test and verification competency. The inputs prior to optimization are listed on the right and resulting output parameters on the left. For example, given the quality test for the Pro14n camera the input provided is an electronic digital image. The Maxwell's software algorithm analysis together with trained image quality engineers and scientists are the core capabilities that ensure help to ensure quality control and final testing of product. The output parameters tested and verified are (a) color calibration, (b) flair, (c) pixel noise index, (d) pixel grain index, (e) banding performance, (f) streaks, and (g) registration.

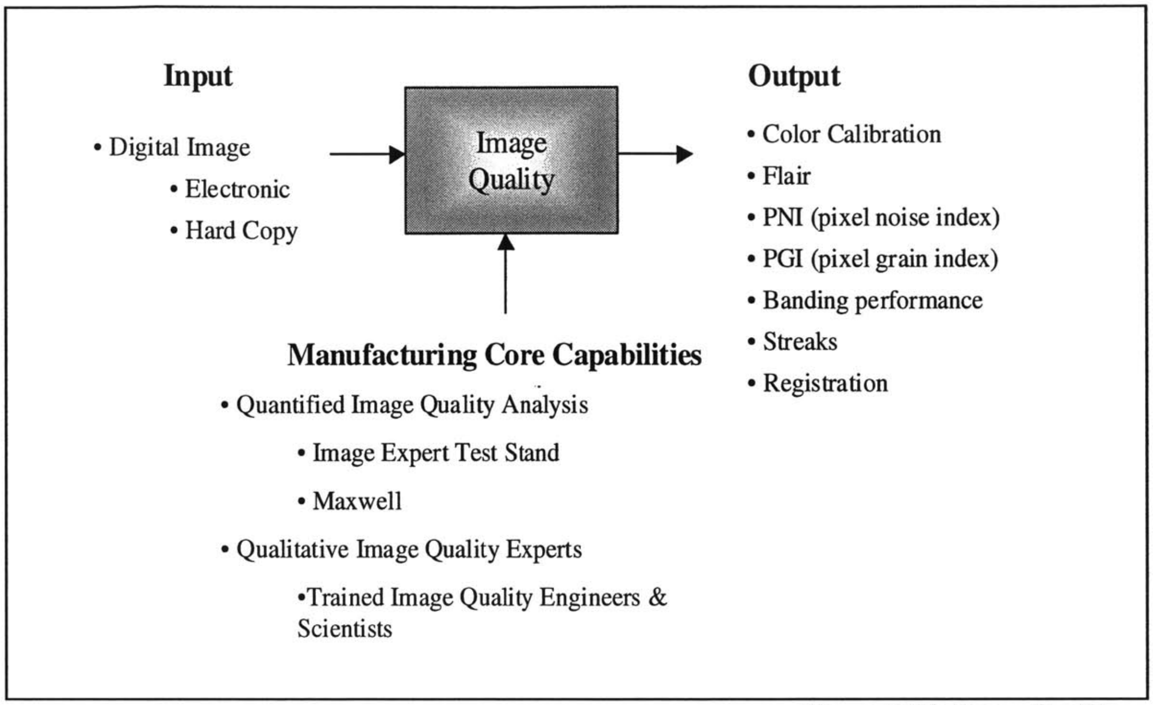

Figure 3-14: Image Quality

3.4 Summary

Kodak's strategic dynamic control of image engines allows the firm to continuously enhance internal learning. This avoids dependence on other players in the value chain, resulting in increased profits. In addition, strategic dynamic control of image engine core competencies provides Kodak with a baseline to recognize and value potential growth opportunities.

Assessing the future product roadmaps, the core competencies highlighted in this chapter remain viable across a variety of product lines. There are several new products in the roadmap where new core competencies are required for manufacturing and assembly. For these products development funding is essential in order to continue internal learning and maintain competitive advantage.

CHAPTER FOUR: MINI-FAST SCAN QUALITY CONTROL

4.0 Introduction

Quality control measures were implemented for the Mini-Fast Scan, the image engine in the Computer Radiography (CR) system. First the critical quality control measurements were determined, and a database was created in SQL for data management purposes. Secondly, a thorough Gage R&R study was created, performed, and examined for this subassembly. An ARIMA time series model was then utilized to assess any time dependencies between batches. Lastly statistical process control was implemented for this assembly process.

4.1 Kodak CR 850/900 System

The Kodak CR 850/900 system provides an efficient method for capturing and converting radiographic images into digital form. First, the x-ray system generates a standard radiation beam that passes through the patient. The output from this test is then captured on a phosphor plate rather than the traditional radiographic film. The phosphor plate containing the latent X-ray image is then scanned using the CR laser beam scanner. The digital scanned image from the phosphor plate (sometimes referred to as a cassette) is then displayed on the computer monitor screen contained within the CR system. The phosphor plate is then erased and reused for another patient's X-ray exposure.

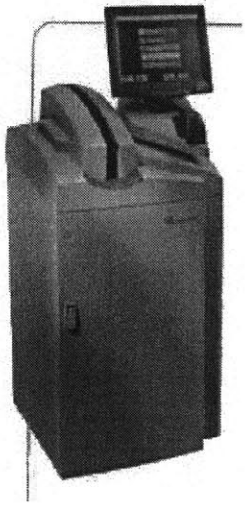

Figure 4-1: CR850

The CR system both processes and performs image reviews. The image processing software supports reduced read time by providing physicians with further diagnostic built-in test. Once the image is analyzed, the radiologist will utilize the configured PACS or Picture Archiving and

Communication System to send the image to the appropriate destinations. The PACS system involves computerized management and transmission of radiological images.

Image acquisition primarily occurs by three methods: (1) A film digitizer converts conventional radiographs to digital form for transmission over a network, (2) Computed radiography (CR), and (3) Digital Radiography (DR). The DR system is a direct x-ray capture system – the direct detector design automatically converts x-rays into electronic images, resulting in a high precision signal profile and resolution image.[34]

The dimension of this CR850 system is 25 X 29 inches. This system can process up to 104 cassettes an hour; increasing hospital efficiency to better manage patient documentation (the system includes a bar-code reader for the cassette). The system greatly improves productivity, particularly for areas such as the ER where the digital image can be sent through the PACS network to the appropriate physician for interpretation. (The system can network up to ten remote operations panels.)[35]

The Computer Radiography and Digital Radiography systems together with PACS have greatly transformed the field of radiology. As more doctors gain exposure to the system, it has become fully apparent that film-based systems for both analyzing and managing clinical images do not possess the same caliber of quality, as do digital imaging systems. As a result of this finding, the dissemination of this technology over the past two or three years has been increasing rapidly.

4.2 Mini-Fast Scan Assembly

The Mini-Fast Scan is the image engine subassembly for the CR850. During the past year the subassembly has been manufactured in Division A. Assembly of the mini-fast scan is reliant on the accurate laser alignment of the laser beam diode – this manufacturing competency was described earlier in chapter three. The laser beam functions as an "excitation mechanism", serving as a source of energy that "pumps" or excites the atoms on the phosphor plate from a lower to higher energy state. The collector subsystem is then responsible for converting or capturing the atoms from their higher energy state into digital form. Figure 4-2 illustrates the key components contained in the Mini-Fast Scan.

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[34] "Go Directly from Capture to Diagnosis," Eastman Kodak Company, 2001, <http://www.kodak.com/go/health>.

[35] "Kodak DirectView CR 850 System," Eastman Kodak Company, 2003, <http://www.kodak.com/go/health>.

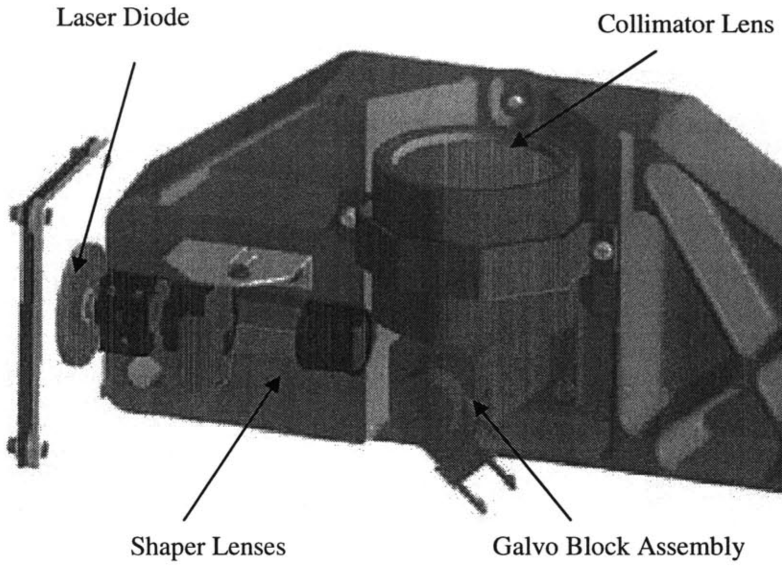
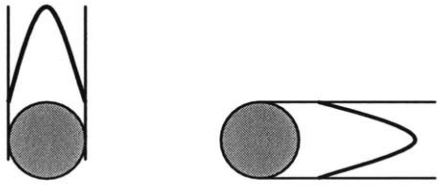


Figure 4-2: Mini-Fast Scan

The high-level design features are as follows: First, the laser diode nested in the circuit board shines the laser beam through a series of shaper lenses. The Galvo Block assembly then sweeps the laser beam through the Collimator Lens onto the phosphor plate. The Galvo Block assembly is configured to enable the laser beam to sweep through all of the pixels found on the phosphor plate.

4.3 Mini-Fast Scan Quality Control Measurements

In order to ensure customers the highest image quality several key measurements are taken once the Mini-Fast Scan has been assembled. The critical measurements include (1) laser spot size and (2) Modulation Transfer Function (MTF). The laser spot size was taken at several specified locations for both page and line. The 'spot size page' as the name suggests is the dimension of the laser spot size parallel to the width of the phosphor plate. The 'spot size line' is the dimension of the laser spot size perpendicular to the width of the phosphor plate (or parallel to the scanned line). The spot size line and spot size page are illustrated below:



Spot Size Page Spot Size Line

Figure 4-3: Spot Size

In order to produce a high-resolution image, both the spot size page and spot size line should satisfy the given requirement specifications at all pixel locations.

The plot of the MTF against frequency is "an almost universally applicable measure of the performance of an image-forming system," that can be applied to systems such as film, lenses and phosphors. MTF can also be referred to as frequency response, sine wave response or contrast transfer. The optical system is frequently tested using a bar chart such as the one illustrated below.

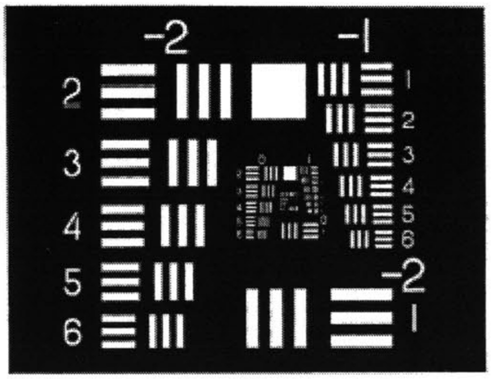


Figure 4-4: Bar Target[43]

The chart consists of several different series of alternating light and dark bars. The finest set in which the line structure can be discerned is called the system's "limit of resolution." If the series has a frequency of N lines per millimeter then the period is equal to 1/N millimeters. A plot of the brightness function is then a square wave with a period of 1/N.[36]

The spread function is added to the brightness function to create the final image, as highlighted in Figure 4-5. Figure 4-6 illustrates the general methodology used to determine the spread function. Given an image, the numbers of spots Nx for a given Δx are counted for each increment. The line spread function A(x) is thus the graph of N_x versus x.[37]

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[36] Hecht, E., Optics, New York: Addison Wesley Publishing Company, 1990.

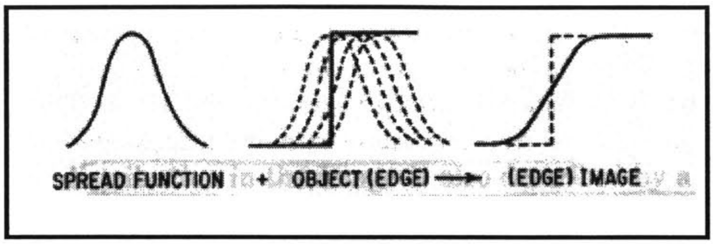

Figure 4-5: Image Creation[44]

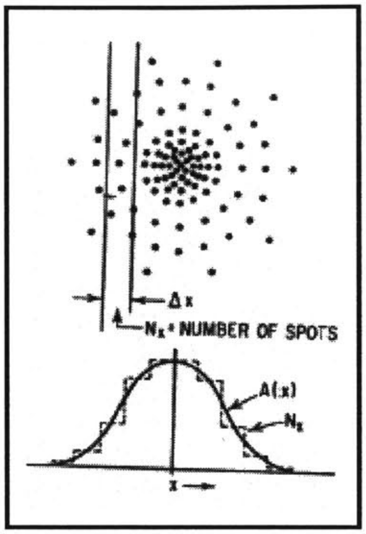

Figure 4-6: Spread Function[44]

When the test pattern or bar target segment becomes finer, the contrast between the light and dark areas of the image is reduced. Figure 4-7 illustrates the change in image illumination resulting from the reduction in object brightness. The modulation transfer function is the ratio of the modulation in the image to the modulation in the object. The modulation for this image can be represented by the following equation: Modulation = (max – min)/ (max + min) where the image illumination levels as illustrated in Figure 4-7 are represented as min and max.[38]

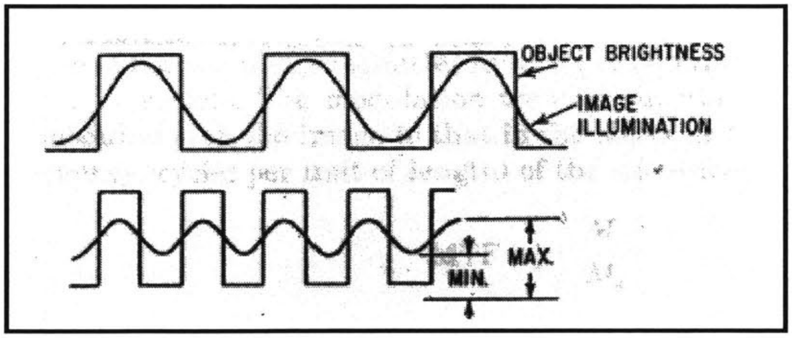

Figure 4-7: Image Illumination[44]

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[37] Smith, W., Modern Optical Engineering, the Design of Optical Systems 2nd Edition, New York: McGraw Hill, 1990.

[38] Smith, W., Modern Optical Engineering, the Design of Optical Systems 2nd Edition, New York: McGraw Hill, 1990.

The graph below illustrates two MTF measurements taken for a system such as the Mini-Fast scan, with lens A and B. For these set of measurements, both begin with a zero frequency DC offset. Lens B has a higher limit of resolution; however, overall when the frequency is less than the limiting resolution lens A exhibits higher performance.

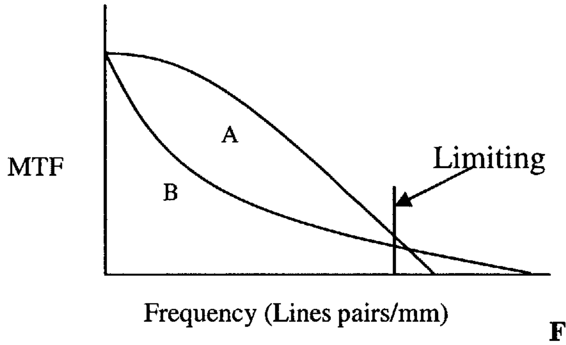

Figure 4-8: MTF Comparison

4.4 Gage Repeatability and Reproducibility

Gage Repeatability and Reproducibility (Gage R&R) was run to assess the total equipment variation of the Mini Fast Scan Assembly fixtures. Analysis of the Mini-Fast Scan process can't be appropriately analyzed until the variability of the test fixtures had been determined.

Repeatability can be defined as the ability of a testing system to provide precision under a limited set of specified conditions. These specified conditions specify that the testing system include (1) the same set of test fixtures, (2) the same group of subsystems, (3) the same environmental conditions, (4) same day or time frame, and (5) the same group of operators. The purpose for performing the gage repeatability tests is therefore to measure the variability in measurements, for the case when one operator uses the same gage or fixture, in measuring identical characteristics of the same parts. Figure 4-9 illustrates the repeatability measurements together with the true average value.

Reproducibility can be defined as the ability of a testing system to provide precision under a broader set of conditions. These broader sets of conditions include (1) the subsystems are retested by different operators and (2) utilizing different fixtures. The purpose for performing the gage reproducibility tests is therefore to measure the variation in the average of measurements utilizing the same gage or fixture with different operators. Figure 4-10 illustrates the reproducibility measurements with respect to the true average value.

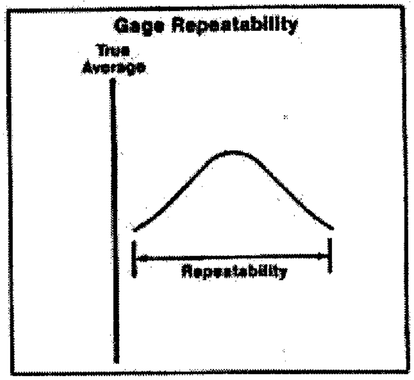

Figure 4-9: Gage Repeatability

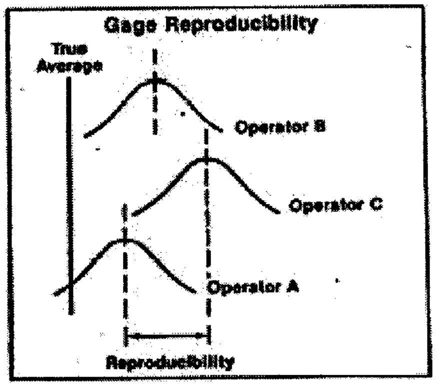

Figure 4-10: Gage Reproducibility

The TCI ratio or Test Capability Index is a ratio of the specification over the standard deviation. The formula is as follows: TCI Ratio = (Upper Spec – Lower Spec)/ ($6\sigma_{test}$)
This ratio provides a valuable parameter for quantifying the variability in the test fixture.
The percentage of the total specification contributed by variation in the measurement system can be determined by dividing 1/TCI.

4.4.1 Background

The experiment was set-up to analyze the repeatability for part measurements and the reproducibility due to operators for the Mini-Fast Scan Assembly fixtures. The purpose was to then assess the contribution from both variances in repeatability and reproducibility, to the total variability of the system.

4.4.2 Objective

The goal for this study was to indicate (1) the percentage of the total variability determined by repeatability or the Mini-Fast Scan Assembly fixture, and (2) the percentage of the total variability determined by reproducibility or the operator. The diagram below illustrates the process implemented to conduct this Gage R&R procedure.

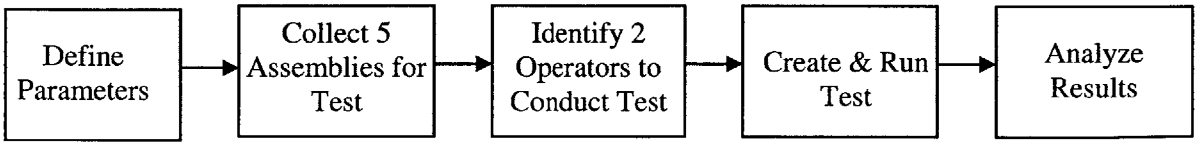

Figure 4-11: Gage R&R

4.4.3 Procedure

Two operators measured five Mini-Fast Scans after they were assembled on two separate fixtures. The test was configured with three replicated trials, and randomized in JMP using a uniform normal randomization sequence. Measurements were taken for laser positioning (spot size page and spot size line) at 15 locations. In addition laser characterization (MTF) for contrast parameters a-f was taken at the center position.

4.4.4 Results

The TCI for all of the metrics were determined and assessed according to the following framework: (a) TCI > 4.0 are passed, (b) 2.0 < TCI < 4.0 require further examination, and (c) TCI < 2.0 fail. The results obtained are illustrated in the table below.

TCI	Laser Positioning	Laser Characterization
TCI < 2.0	6.7%	33.0%
2.0< TCI <4.0	10.0%	58.3%
TCI > 4.0	83.3%	8.7%

Figure 4-12: Gage R&R Results

- *Laser Positioning*: Analysis of the data demonstrated that 83.3% of the data clearly passed with TCI values above 4.0. Approximately 10% of the values failed. These measurements that failed were all thoroughly analyzed, 100% of these values were proven to be independent between test fixtures. More importantly, it should be noted that the data contained a small degree of both operator and fixture variance – there was a high degree of variance displayed within the part.
- *Laser Characterization*: Analysis of the data demonstrated that 33% of the TCI measurements failed. In addition, 58.3% of the measurements taken needed further examination. Similar to the laser positioning data, there was a small degree of both operator and fixture variance, and a high degree of variance within the part. The data management system described in the next section was utilized as a tool to understand the poor MTF measurement performance.

4.5 Data Management

The old data management system was highly inefficient for analyzing data. In order for an engineer to analyze one data specification, one would have to pull the desired data point from hundreds of files that were stored according to date. For example, in the old system the MTF measurements taken at the center position were placed into separate ASCI files. In addition, screen captures illustrating the Gaussian distribution and required specifications for each MTF value at center (six total values) were saved. The operator manually entered all fifteen locations into an EXCEL file for both spot size page and spot size line. As a result, under the old system analysis of data trends were extremely difficult to carry out.

A new data management system was implemented for the Mini-Fast Scan Assembly. First, a program was created in Labview for measurement and test purposes. Much of the data that had been entered manually by the operator is now automatically uploaded to the program, reducing build time and operator input error. The output data collected from each build is then automatically stored in the SQL database. The SQL database was created to store all of the measurements taken by the operators out on the plant floor.

The database created stores 120 data points for each subassembly. Figure 12 illustrates an example of the types of data stored in the database: (1) the subassembly unit-number, (2) date the measurements were taken, and (3) name of the operator. Examples for the types of measurements captured include the following: (1) the spot size page at a specified location, (2) the spot size line at a specified location, and (3) the MTF for a given parameter and location.

Unit	Name	Date	Spot_Size_Page_1	Spot_Size_Line_1	MTF_Pos1_1
28	Bob	08/03/2003	A	B	C
29	Jim	08/03/2003	D	E	F
30	Jim	08/04/2003	B	F	E
31	Bob	08/04/2003	G	G	C

Figure 4-13: SQL Database

The SQL database has proven an invaluable tool to collect the hundreds of data points that are generated daily for this low volume – high cost product. Once the data is stored in the database the key challenge becomes analyzing the data appropriately. Microsoft's Data Mining research group coined the phrase "panning for gold among the gigabytes" of data.

> *"Data mining is part of a larger process called Knowledge Discovery in Databases (KDD). The discovery part of the process - the part that finds gold among the gigabytes-is data mining. But before you can pull out your tin pan and shake it for gold, you need to gather your data into a data warehouse.... These huge data warehouses contain gigabytes with "hidden" information that can't be easily found using typical database queries, giving rise to the myth that the more data you have, the less you know. Data mining algorithms change all that by finding interesting patterns that you didn't even know were there - like a prospector who discovers gold while trying to build a sawmill."*[39]

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[39] "Panning for Gold among the Gigabytes," Microsoft, August 2003, <http://research.microsoft.com/>.

The database for the Mini-Fast scan was first leveraged to determine the root cause of the poor MTF measurements obtained from the Gage R&R study.

4.5.1 MTF Analysis

Initially all of the MTF data was extracted from the SQL database and placed into JMP for analysis. The MTF Page data displayed a much higher degree of variance than the MTF Line data; the initial analysis then became focused on determining the root cause of this high degree of variance.

After analyzing the JMP data, engineers in Health Imaging determined that the high degree of MTF Page variance was a result of the collimator lens shape. The collimator lens shape was therefore altered to tighten the laser beam sweep range. This in turn significantly reduced the number of MTF aberrations. Examination of the MTF signal before and after the lens change is illustrated below:

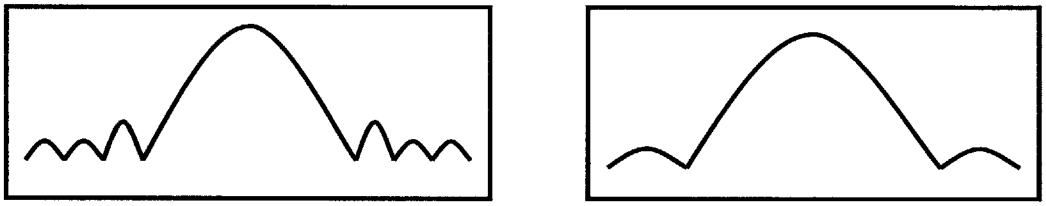

Figure 4-14: Before (left) collimator change and after (right)

The Gaussian MTF signal prior to the lens alteration contained significant side lobes. After the engineering change the MTF signal was much smoother with smaller lobes. The change in the MTF Gaussian distribution served to optimize the MTF measurements and lower the degree of variability.

Control charts provide an excellent means to verify and test whether the implemented design change was successful. Control charts, prior to the collimator lens change, for the MTF Page contrast parameters a – c are plotted in Figures 4-15 through 4-17 respectively for the dates 10/9-10/14. It is crucial to note that MTF_a_Page correlates to the lowest contrast function, while MTF_c_Page correlates to a higher contrast function. The Upper Specification (not illustrated) is 1.0 for all of the MTF measurements.

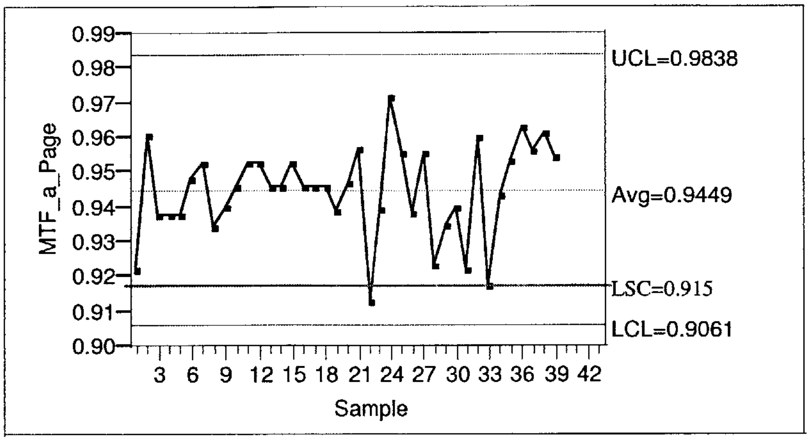

Figure 4-15: MTF_a_Page Pre-Collimator Change

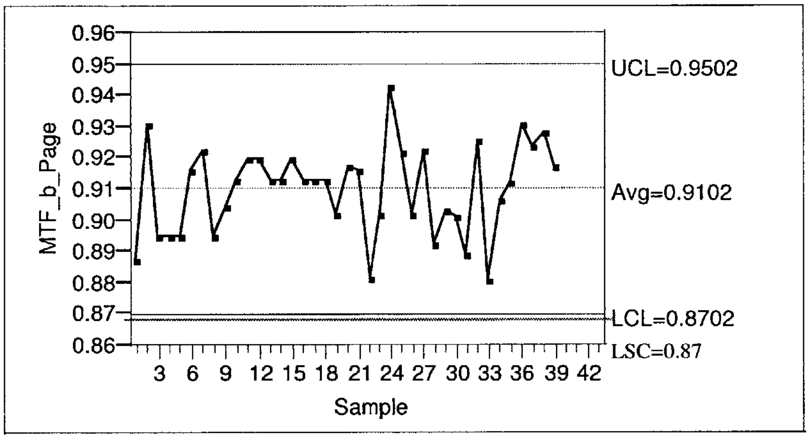

Figure 4-16: MTF_b_Page Pre-Collimator Change

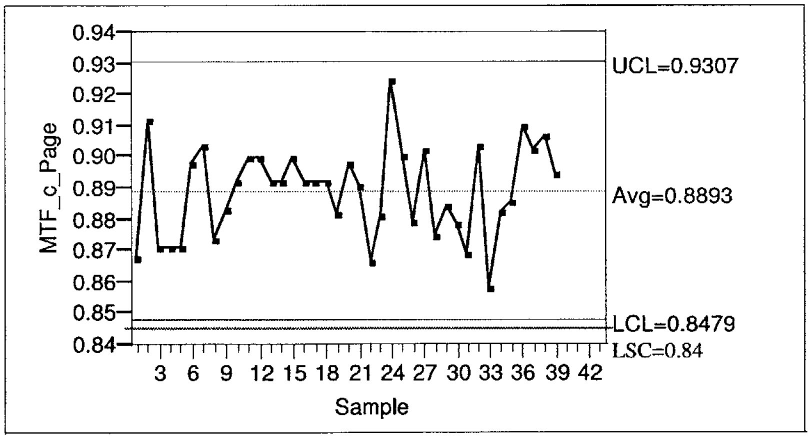

Figure 4-17: MTF_c_Page Pre-Collimator Change

The control charts illustrate that the lower contrast MTF measurements are highly variable, the lower specification for contrast a is inside the lower control limit, while for contrast b and c the lower specification is approximately equal to the lower control limit. This is an enigma since theory would imply that the higher contrast MTF measurements would prove more likely to display a higher degree of variance. Discussion with Heath Imaging engineers did not yield a solution to this perplexing issue.

Supposedly the collimator lens design change was implemented on October 16, 2003. Control charts plotted during the period 10/20 – 10/23 surprisingly do not illustrate any change relative to the period 10/9 – 10/14. There is a high probability that the old lenses, from the inventory stock were utilized during this period; new parts were not utilized until the following week. Therefore, a time delay factor must be taken into account when analyzing the MTF data. Control charts, for the dates 10/29-11/3, for the MTF Page contrast parameters a – c are plotted in Figures 4-18 through 4-20 respectively.

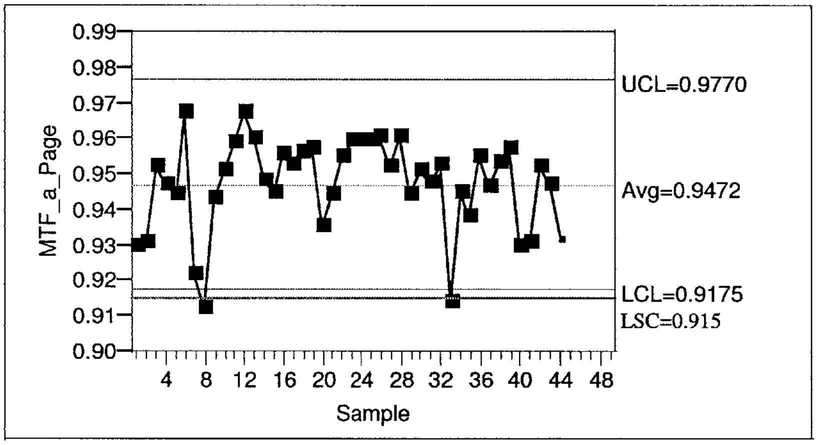

Figure 4-18: MTF_a_Page Post-Collimator Change

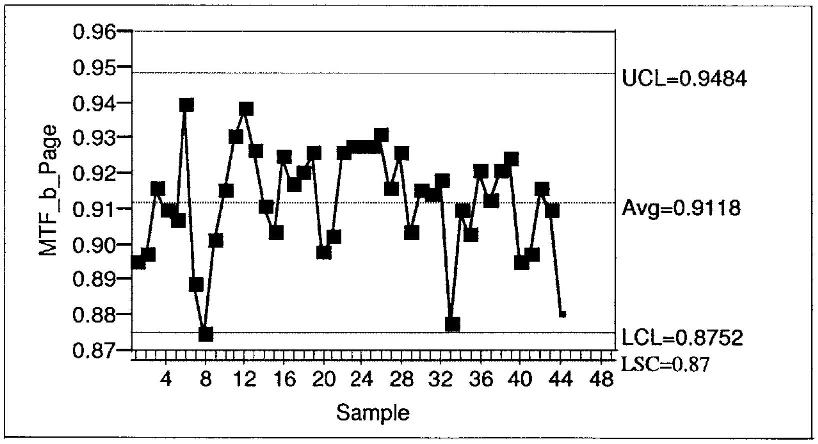

Figure 4-19: MTF_b_Page Post-Collimator Change

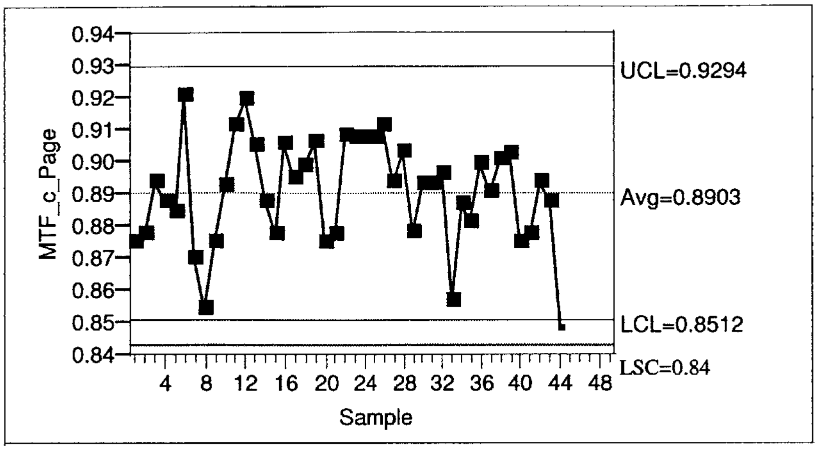

Figure 4-20: MTF_c_Page Post-Collimator Change

For all of the lower contrast MTF parameters at center position, the graphs display the lower specification outside of the lower control limit. Therefore the MTF data are within specification, and it can be concluded that the design change in the collimator lens was successful. Hence the collimator design change was determined as the 'assignable' cause to the high part variance demonstrated for the Gage R&R laser characterization.

4.6 ARIMA Model

The ARIMA model was utilized to further examine the MTF Page measurements and assess whether there were any significant time dependencies. The ARIMA model or Auto-Regressive Integrated Moving Average is illustrated with the following notation ARIMA (p, d, q). The model is utilized to determine the number of past observations and past disturbances that are strongly correlated with current observations. The model can be implemented for stationary, non-stationary and seasonal problems. The autocorrelation function is used to extract any time dependencies. The Autoregressive (AR) portion represents the linear combination of the past p observations. The Moving Average (MR) combination represent the linear combination of the past q disturbances.

The general form of the ARIMA model is shown below:

$$\boxed{\Phi_p(B)(1 - B)^d X_t = \theta_q(B)\varepsilon_f}$$

The B represents the backward shift operator. Φ_p and θ_q are polynomials of order p and q, both are illustrated on the next page:

$$\Phi_p = 1 - \Phi_1(B) - \Phi_2(B)^2 - \Phi_2(B)^3 - \ldots\ldots.\Phi_p(B)^p$$

$$\theta_q = 1 - \theta_1(B) - \theta_2(B)^2 - \theta_2(B)^3 - \ldots\ldots.\theta_q(B)^q$$

In order to formulate an ARIMA nonseasonal model there are a series of rules that must be closely followed. The rules provide detailed guidelines for determining the value of d (order of differencing), the value of p (number of past observations), and lastly the value of q (number of past disturbances). In generating an ARIMA model, first the order of differencing is determined through a series of iterations. Second, the Auto Regressive or p term is calculated. And lastly, the Moving Average or q term is found. The ARIMA non-seasonal model rules are outlined in detail in Appendix Figure A.

4.6.1 MTF ARIMA Models

The ARIMA models were synthesized for all of the MTF Page contrast parameters at center position. In the earlier section control charts were used to assess the variability of the MTF Page data. More importantly the analysis performed was used to determine whether the data was within the required customer specifications. The ARIMA models provide a methodology in which to determine and assess the existence of any time dependencies. Time dependencies in the data can greatly impact control charts results.

4.6.2 Procedure

The ARIMA models for MTF Page were run for contrast (line pairs/mm) parameters ranging from a – f, with a being the lowest contrast and f being the highest contrast. To begin simulating the models it was determined that all of the contrast data would require at least one degree of differencing. All contrast parameter data were run with one order of difference. To appropriately determine the optimum level of differencing, the first model generated was followed by an iteration that utilized 2 orders of differencing.

Once the appropriate differencing orders were determined, both the PACF (Partial Auto-Correlation Function) and ACF (Auto-Correlation Function) were examined for the resultant optimized differencing model [Either ARIMA (0,1,0) or ARIMA (0,2,0)]. The PACF was examined for a positive lag1 term and/or sharp cutoff – both states indicative of a necessary AR term. The ACF was examined for a sharp cutoff and/or negative lag1 term – both states indicative of a necessary MA term.

4.6.3 Results

The results of the ARIMA models are illustrated in Figure 4-21:

	ARIMA (0,1,0)		ARIMA (0,2,0)		ARIMA (0, 1, 1)		ARIMA (0, 2, 1)	
	Std Dev	**Prob I >|t|**	**Std Dev**	**Prob I >|t|**	**Std Dev**	**Prob I >|t|**	**Std Dev**	**Prob I >|t|**
MTF_a_Page	0.01705	0.9172	0.02851	0.9373	-	-	0.01716	0.9577
MTF_b_Page	0.01883	0.9143	0.03155	0.9457	-	-	0.01906	0.9577
MTF_c_Page	0.01976	0.9233	0.03326	0.9457	-	-	0.02004	0.9373
MTF_d_Page	0.02043	0.9414	0.03449	0.9557	-	-	0.02705	0.9373
MTF_e_Page	0.02639	0.9557	0.04515	0.9157	0.02050	0.9557	-	-
MTF_f_Page	0.02972	0.9457	0.05104	0.9299	0.02249	0.9374	-	-

Figure 4-21: ARIMA Results

Each of the MTF contrast page results are analyzed below:

(1) MTF_a_Page – ARIMA(0, 2, 1)

This model has 2 orders of differencing which implies that the data follows a quadratic time trend. The probability that the forecasted data continues the pattern of this trend is 95.77%. The moving average combination of the past q disturbances while present in the model, accounts for less than 1% of the time dependency for the forecasted data.

(2) MTF_b_Page – ARIMA(0, 2, 1)

This model follows a quadratic time trend that is indicated by the order of differencing equivalent to 2. The probability that the forecasted data continues the pattern of this trend is 95.77%. Less than 1% of the time dependency for the forecasted data is reliant on the moving average component.

(3) MTF_c_Page – ARIMA(0, 2, 1)

This model has 2 orders of differencing which implies that the data follows a quadratic time trend. The probability that the forecasted data continues the pattern of this trend is 93.73%. The moving average combination of the past q disturbances while present in the model, account for less than 1% of the time dependency for the forecasted data.

(4) MTF_d_Page – ARIMA(0, 2, 1)

This model follows a quadratic time trend that is indicated by the order of differencing equivalent to 2. The probability that the forecasted data continues the pattern of this trend is 93.73%. Less than 1% of the time dependency for the forecasted data is reliant on the moving average component.

(5) MTF_e_Page – ARIMA(0, 1, 1)

This model exhibits 1 order of differencing which implies that the data follows a constant average trend. The probability that the forecasted data continues the pattern of this trend is 95.57%. The moving average combination of the past disturbances q, account for less than 1% of the time dependency for the forecasted data.

(6) MTF_f_Page – ARIMA(0, 1, 1)

This model exhibits 1 order of differencing which implies that the data follows a constant average trend. The probability that the forecasted data continues the pattern of this trend is 93.74%. Again, less than 1% of the time dependency for the forecasted data is reliant on the moving average component.

4.6.4 Analysis

The models illustrate a higher degree of dependency for the lower contrast MTF page data. This result correlates with the earlier theory from the control charts that the lower contrast MTF data is more variable and exhibits a higher sensitivity than the higher contrast MTF. There are two hypothetical reasons for the time dependency shown in the model: (1) Operator improvement and (2) Lens quality improvement.

Operator improvement is predicted to play a large role in the time dependency illustrated. The data for this ARIMA model was captured for the time period beginning 10/10/03 and ending 11/3/03. In the beginning of October a new operator was added out on the plant floor to make a total of three technicians working on this project. The Mini-Fast scan is a difficult product to assemble, and therefore the learning curve for this subassembly is quite high. Hence, it would be expected that operator learning would play a large role in the time dependency factor exhibited.

The collimator lens change was initiated on 10/16/03, however; as illustrated in the previous section due to a large older inventory stalk the design change was not implemented until late October. Thus the ARIMA model should reflect this design change as a dependency in MTF contrast. As demonstrated earlier, the lens change displayed a higher degree of impact for the lower MTF contrast measurements than the higher MTF measurements. Subsequently one would expect to see a higher degree of time dependency on the lower contrast MTF values.

4.6.5 ARIMA Conclusion

In order to further quantify the degree to which (1) operator improvement and (2) lens quality improvement played for the time dependency shown, further ARIMA models were simulated. The models were examined for the period 10/29 – 11/3. This period is representative of a time frame for which the collimator design change was implemented, and an additional operator had been working for approximately one month. The results of the ARIMA model for this period are illustrated in Figure 4-22:

<table>
<tr><th></th><th colspan="2">ARIMA (0,1,0)</th></tr>
<tr><th></th><th>Std Dev</th><th>Prob I >|t|</th></tr>
<tr><td>MTF_1.5_Page</td><td>0</td><td>-</td></tr>
<tr><td>MTF_2.2_Page</td><td>.01704</td><td>.9779</td></tr>
<tr><td>MTF_2.6_Page</td><td>.00184</td><td>.9730</td></tr>
<tr><td>MTF_2.8_Page</td><td>.00207</td><td>.9730</td></tr>
<tr><td>MTF_4.1_Page</td><td>.00343</td><td>.9651</td></tr>
<tr><td>MTF_4.3_Page</td><td>.00443</td><td>.9651</td></tr>
</table>

Figure 4-22: Further ARIMA Analysis

The ARIMA model displays a very weak time dependency, with a differencing factor of one, for all of the MTF contrast parameters. Therefore it can be concluded that the design change in the collimator lens and/or the learning curve of the new operator, contributed to the stronger degree of time dependency exhibited for the lower contrast MTF. It should be noted, however; that at this juncture it remains unclear as to why there is still a weak time dependency factor shown for all of the MTF parameters. Repeated ARIMA model tests should be conducted to investigate this trend; if similar results are obtained, the source producing these undesirable results must be determined.

4.7 Statistical Process Control

This section provides an introduction to Statistical Process Control (SPC). There are four states for any quality control process. These four possibilities are as follows: (1) Ideal State, (2) Threshold State, (3) Brink of Chaos, and (4) State of Chaos. Figure 4-23 evaluates the manufacturing process, and determines whether this process produces some 'non-conforming product' or is on the 'brink of chaos.'

	Some Nonconforming Product Produced	Conforming Product Produced
Process Displays Control	***Threshold State***	***Ideal State***
Process Displays Lack of Control	***State of Chaos***	***Brink of Chaos***

Figure 4-23: Quality Control States[40]

A description of the framework states follows:[41]

The Ideal State

- The process is 100% predictable and produces 100% conforming product. The process is inherently stable over time.
- The process average must be maintained at the appropriate level.
- The natural process must operate in the appropriate range of the product specifications.
- The control charts maintain process control and alert the operator when the process begins to lose stability.

The Threshold State

- The process is 100% predictable, with some nonconforming product.
- In order to achieve the Ideal State, the process or product specifications must change.
- The control charts can be used not only to maintain a consistent and stable process, but also in helping to determine when to make adjustments to the process and/or product specifications.

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[40] Wheeler, D., Understanding Topics in Statistical Process Control, New York: SPC Press Inc., 1995.
[41] Wheeler, D., Understanding Topics in Statistical Process Control, New York: SPC Press Inc., 1995.

The Brink of Chaos

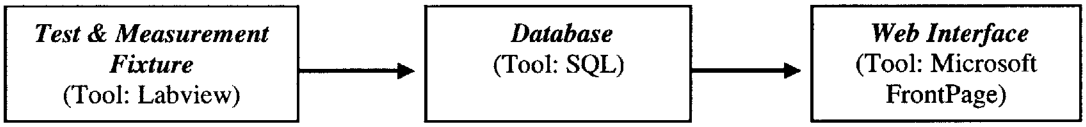
- The process in this state is out of statistical process control, even though production is producing 100% conforming product.
- Instability will continue to change the product characteristic.
- Quality and conformance to specification is highly variable.

The State of Chaos

- Process is out of control and producing some nonconforming product.
- ‘Assignable’ causes dictate the process.
- Elimination of the ‘assignable’ causes is the only way to move a process out of the State of Chaos.

4.7.1 SPC Implementation

Statistical process control (SPC) was implemented for the Mini-Fast Scan cell to track the daily manufacturing process. The process for implementation was followed from the work of Christine Lindsey (LFM 04’). The overview of this process is as follows:



The first two steps (1) test and measurement and (2) database, were described above in the database management section. Lindsey created an SPC web template utilizing Microsoft FrontPage. The web template uses an active link to capture data from the SQL database for viewing in FrontPage.

The statistical process control template created for the Mini-Fast Scan leverages the work of Lindsey. The web site created gives users the ability to first select one of the four criteria: (1) spot size position page, (2) spot size position line, (3) MTF Page, or (4) MTF Line. The user then enters the appropriate parameter – for spot size the user would select one of fifteen positions, while for MTF the user would select one of six contrast measurements. The web site then provides the quality control chart for the desired parameter.

4.7.2 SPC Interpretation

The graphic below provides a high-level decision tree for analyzing the resulting statistical process control charts. After the design change for the collimator lens the Mini-Fast Scan subassembly fully passed the Gage R&R test for both laser positioning and laser characterization. Therefore one can assume the process displays controlled variation.

The initial assumption is that the data is predicted to fall between the appropriate control limits. It should be noted that the Shewart control charts use control limits that are placed at a distance of three sigma units both plus and minus from the average data measurement line. As demonstrated earlier, the upper and lower control limits must fall inside of the upper and lower specification earlier in order for control charts to be effective. The generated SPC chart should be compared to determine whether the data falls inside and/or outside of the specified control limits.

- *Data falls inside the control limits*: Process may be classified as stable. The user should continue monitoring the situation.
- *Data falls outside the control limits*: Process can be classified as unstable. The user should begin to take appropriate action such as root causal analysis to determine the source of instability.

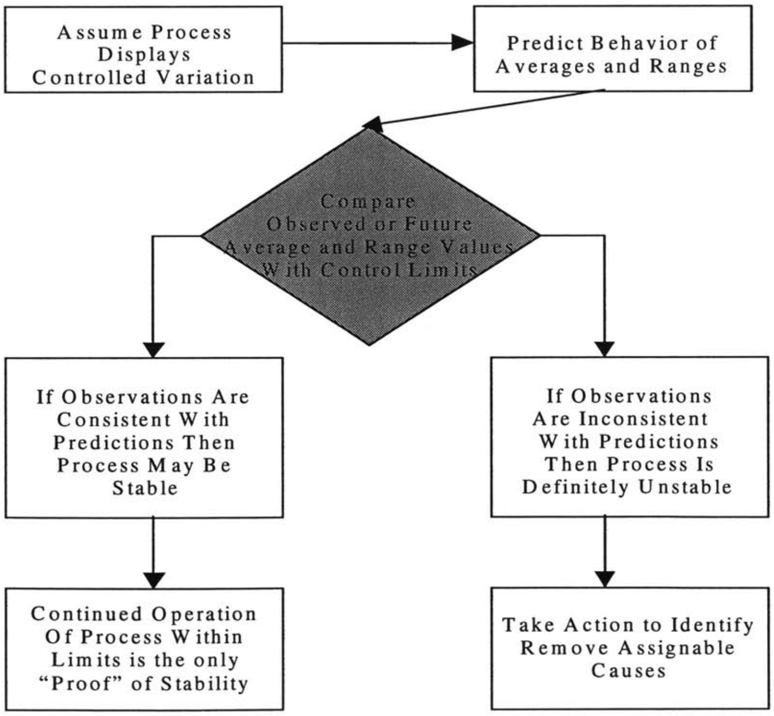


Figure 4-24: Decision Tree for Control Charts[42]

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[42] Wheeler, D., <u>Advanced Topics in Statistical Process Control</u>, New York: SPC Press Inc., 1995.

4.7.2 Summary

Quality control measures were implemented for the Mini-Fast Scan. A Gage R&R was created, implemented and analyzed. Due to the variance in the laser characterization predicted by the Gage R&R, an engineering design change was initiated for the collimator lens. Subsequent control charts demonstrated that the change was successful. An ARIMA time series model was then utilized to assess any time dependencies between batches. Statistical Process Control was then implemented for this assembly process.

CHAPTER FIVE: VALUE CHAIN MAPPING

5.0 Introduction

> *"A dominant position in core products allows a company to shape the evolution of applications and end markets....if a company is winning the race to build core competencies (as opposed to building leadership in a few technologies), it will almost certainly outpace rivals in new business development."*[43]

The value chain maps provide a high-level framework from which to assess Kodak's transition from analog to digital. The digital world has completely revamped the playing field. In the shift from analog to digital, the value has shifted from a focus on output consumables such as thermal paper and silver-halide film to digital equipment. The digital value chains illustrate that a large segment of Kodak's value proposition is in the image engine (i.e. modular subassembly that directly drops into digital equipment). Simply stated in the quote highlighted above, further development of core competencies will help to ensure strategic dynamic control to maintain competitive advantage for core products. During the transition process Kodak's supply chain strategy must realign with a new business strategy focusing in digital technology.

5.1 Vertical Integration

Value chain analysis provides a framework when considering the value chain segments that bring economic surplus. In addition, this analysis highlights those portions of the chain the firm should consider forward and/or backward integrating. In a horizontal market, competition is fierce. Entrance from emergent competitors expands the number of product offerings in the market, thereby increasing buyer power and hence reducing the profit margin. In contrast to horizontal markets, competitive advantage in vertical markets results from economies of scale. Competition is small in comparison to the horizontal structure in part due to slower speed to market. Fine's Double Helix illustrated below demonstrates the way in which product or industry structures transition from integral/vertical to modular/horizontal structures.[44]

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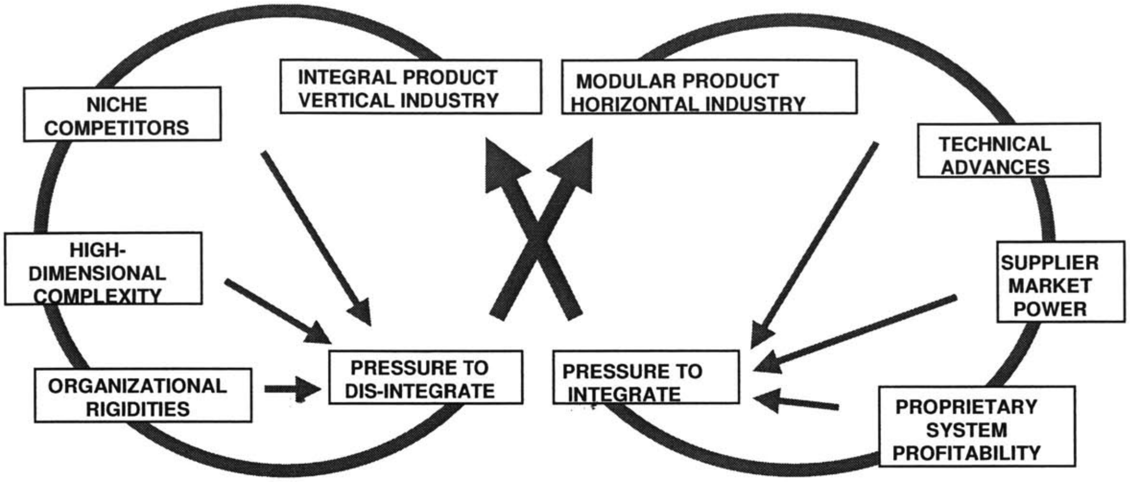
[43] Fine, C., Clockspeed: Winning Industry Control in the Age of Temporary Advantage, Reading, MA: Perseus Books, 1998.

[44] Fine, C. and Whitney, D., "Is the Make-Buy Decision Process a Core Competence?" Logistics in the Information Age, Servizi Grafici Editoriali, 1999, pp. .31-63.



Fine & Whitney, "Is the Make/Buy Decision Process a Core Competence?"

Figure 5-1: Fine & Whitney, Integral vs. Modular

Stuckey and White define economic surplus as the return an enterprise receives in excess of its full costs of being in the business. They further state that exceptional returns from economic surplus does NOT stem from value added or closeness to the customer. Their recommendation is that firm should enter into those stages of the industry value chain where the most economic surplus is available. In the severe downsizing efforts that have occurred recently, managers will mistakenly discard some activities that are critical for strategic control and form some alliances that result in "institutionalized piracy".[45]

The value chain maps for the following lines of business have been drawn: (1) Health Imaging, (2) Consumer Imaging, including Kodak Professional, (3) Entertainment Imaging, and (4) Document Imaging. For all of the value chains the traditional value is shaded in yellow, the consumables in turquoise, and the image engines in green.

5.2 Health Imaging

The analog value chain below illustrates a high-level chain. To begin, the HMO contracts the x-ray equipment to a hospital or physician. The physician (i.e. most often a radiologist) will use the x-ray equipment to capture the patient's image onto film. The film is subsequently developed using a wet processor. Lastly, the film is analyzed by the physician and archived in the patient's folder. The value in the analog value chain is found in the undeveloped film.

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[45] Stuckey, J. and White, D., "When and When Not to Vertically Integrate," Sloan Management Review, vol. 34, no. 3, 1993, pp. 71-84.

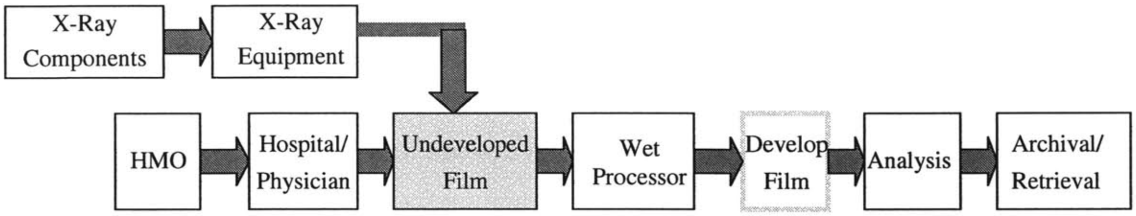

Figure 5-2: HI Analog Value Chain

In the transition from analog to digital there are two separate value chains: (1) computer radiography and (2) digital radiography. These two value chains are both illustrated separately below. In the computer radiography chain, the image from the X-ray equipment is stored on a phosphor plate. The phosphor plate can be reused multiple times, typically over a period of several years. In comparison to the value proposition of film in the analog value chain, there is only a small profit margin in the phosphor plate consumable.

The phosphor plate is then scanned using the computer radiography system. There are a series of platforms for this product, ranging from the desktop CR500 model to the CR950 that can scan several phosphor plates simultaneously. The image engine, in this case the Mini-Fast Scan, reads the image from the phosphor plate and a series of photo-multiplier tubes captures the image. The resulting digital image is then processed using digital signal processing. Lastly, the digital image is then stored using the Picture Archiving Communication System (PACS).

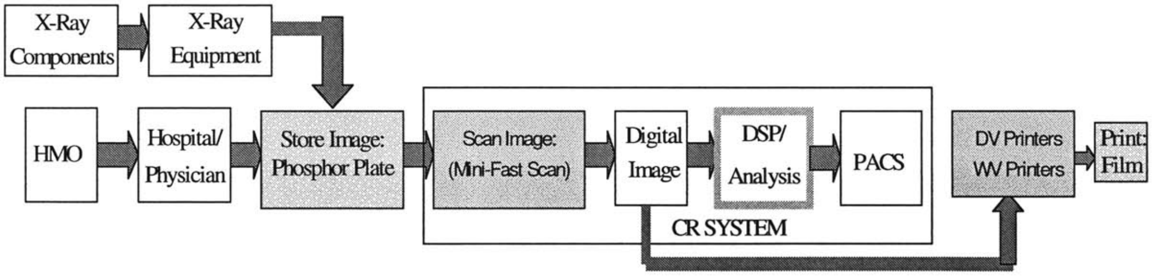

Figure 5-3: HI CR Digital Value Chain

The digital image can be viewed from specially designed monitors or printed out onto film. Kodak designs and maintains two portfolios of printers: (1) Dry View and (2) Wet-view. Two years ago, Kodak acquired a company in Oakdale, Minnesota for the dry view printer technology.

The digital radiography value chain below is significantly different from the computer radiography chain. In this chain the x-ray equipment is integral to the digital radiography equipment. The equipment is characterized most simply as large area flat-panel solid state detectors with integrated thin-film transistor readout mechanisms. Industry experts view the computer radiography systems as a transitional technology and predict the digital radiography systems will dominate market share because of their "superior image quality, intrinsic robustness, and compact design."[46]

Similar to the computer radiography systems, in the digital radiography system the digital image is processed using digital signal processing and stored with the PACS system. It is essential that Kodak play an active role more upstream in this chain. In order to integrate the DR system effectively, the firm must have the resources to understand x-ray equipment technology. Without this knowledge, Kodak will not be able to efficiently design, integrate, and service the DR equipment.

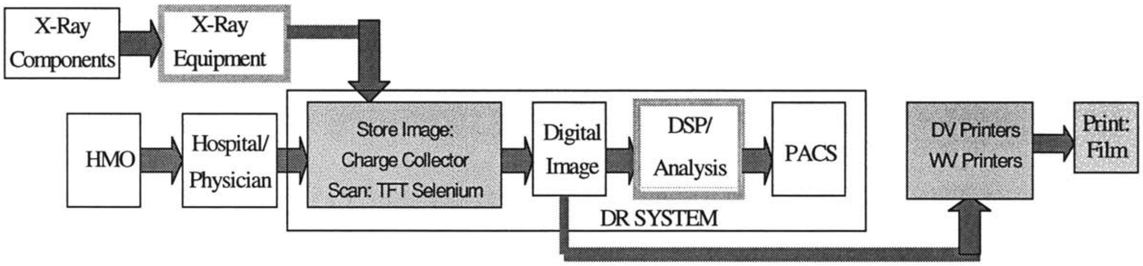

Figure 5-4: HI DR Digital Value Stream

In analyzing the shift from analog to digital for Health Imaging, there are two critical changes. First, the value has completely shifted away from film consumption to a focus on Kodak's digital equipment. And second, while Kodak's "crown jewel" for both the computer radiography and digital radiography systems are centered in digital signal processing, control of the image engine is critical in order to both enable and optimize Kodak's image processing capabilities. Hence strategic dynamic control of the image engine is essential for the future of both the CR and DR systems.

5.3 Consumer Imaging

In the analog value chain shown below, the traditional value for Consumer Imaging was in the design and assembly of the camera. The consumer purchased the film from the retailer, and after point of use was given two options for development: (1) Wholesale Photofinishing, or (2) Retail Photofinishing. For wholesale photofinishing the undeveloped film is trucked to a central

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[46] "Introduction to Digital Radiography: The Role of Digital Radiography in Medical Imaging", Eastman Kodak, 2000, <http://www.kodak.com/go/health>.

location for development. In retail photofinishing the film is developed directly in the store. From the buyers' perspective, the primary differences between the options were development time and price. In the traditional value chain there is a minimal degree of value in the camera equipment. Foremost, Kodak's value proposition has been in the consumer purchasing of film, and subsequent development of this film onto silver halide paper.

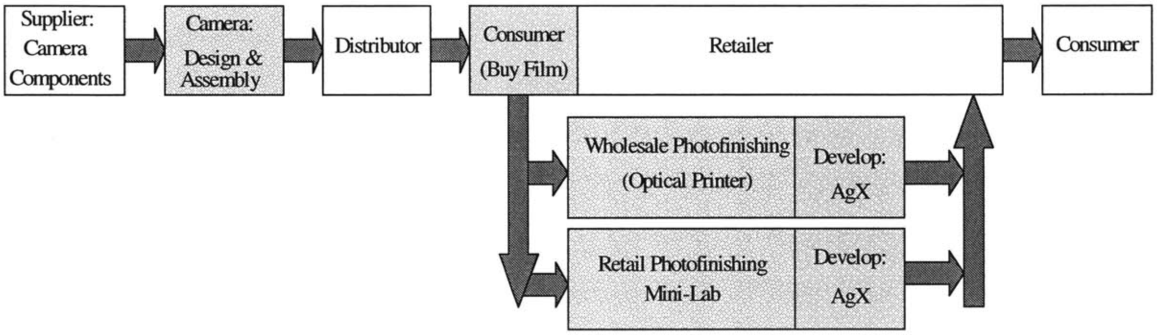

Figure 5-5: CI Analog Value Chain

In the analog to digital Consumer Imaging value chain, the traditional value is in the design and assembly of the camera (similar to the analog chain). In this value chain there remains significant consumable value in the purchase and development of film. In the analog to digital chain the consumer has three film development options: (1) Wholesale Photofinishing, (2) Retail Photofinishing, and (3) Kiosk. For all of these options the analog input image capture is converted to a formatted digital output image to leverage higher image quality capability. It should be noted that there is an image engine contained within each one of these systems. The name of the image engine is listed in parenthesis; all of these image engines are reliant on submicron laser alignment competency for assembly.

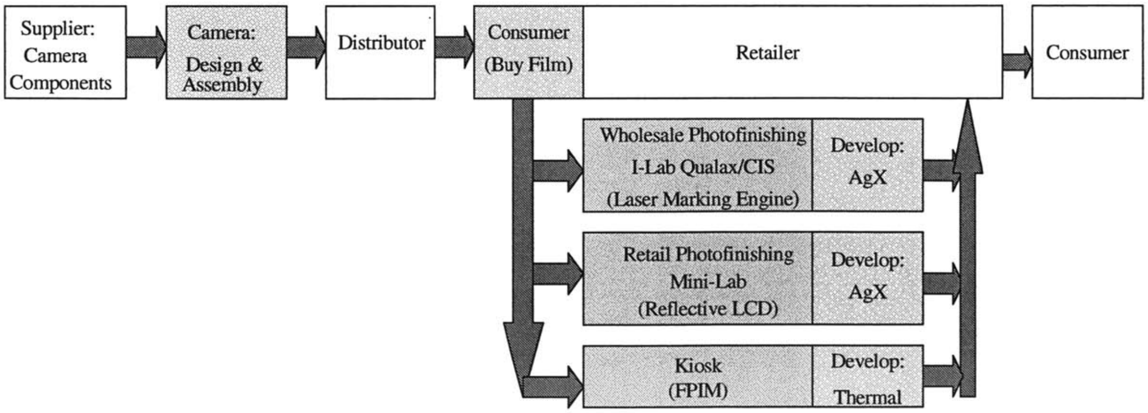

Figure 5-6: CI Analog to Digital Value Chain

There are several key reasons that allow the digital value chain to be differentiated from the analog to digital chain. First the consumer has many more print platform options. The consumer has the option to develop digital prints through a retailer or in the convenience of his/her home. The retail channels are equivalent for both the analog to digital chain and for the pure digital chain. The home printing option is a new market segment for Eastman Kodak. The home printer option is currently in the research and development stages.

Secondly, in this digital value chain there is significantly more value in the design and assembly of the digital camera. To a lesser degree here than in other chains, in order to maintain strategic dynamic control of the consumable profit margins, it is important to play large role upstream in the development of digital camera equipment. By controlling digital equipment, the firm can ensure usage of their own thermal paper.

Lastly, the organic light-emitting diode or OLED display is highlighted in green because there is high potential value of integrating this display with the desktop home computer. In displaying digital photos, the OLED display could potentially provide consumers with higher image quality for viewing. The following quote summarizes the potential strategic value in the OLED display:

> *"....OLED technology is positioning to pave the way for a revolution in display devices, from thinner and lighter handheld devices to wall mountable television systems. It will enable more devices to display and use pictures, accelerating the use of pictures as information in the infoimaging market."*[47]

In May of 2003, Eastman Kodak displayed the world's first OLED camera product, the *EasyShare* LS633 zoom digital camera, with a full-color active matrix OLED display. The display is currently being manufactured by SK Display Corporation, a joint venture between Sanyo and Kodak. According to research firms such as DisplaySearch and Stanford Resources, the OLED display market is predicted to reach up to $3 billion by 2007. Market research has shown several technologies will incorporate the OLED technology including, PDAs, DVDs and mobile phones[48].

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[47] "Kodak Licenses OLED Technology to Opsys Limited of UK," Eastman Kodak, Aug. 2003, <http://www.kodak.com/US/en/corp/display/>.

[48] "Kodak Brands OLED Displays," Eastman Kodak, Aug. 2003, <http://www.kodak.com/US/en/corp/display/>.

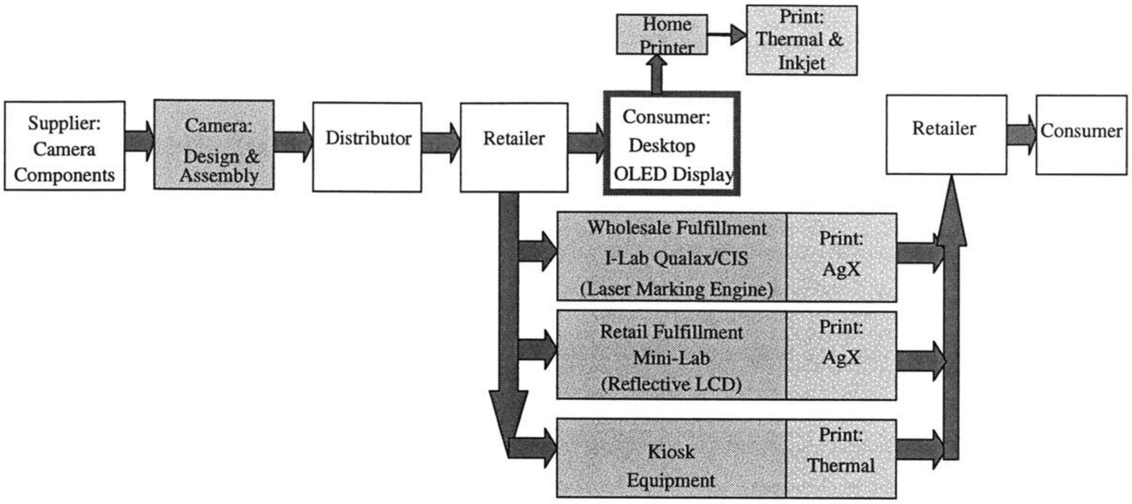

Figure 5-7: CI Digital Value Chain

Examination of the current digital value chains illustrates a wide variety of consumer digital print platform options. Currently only 21% of households own digital cameras. As more households turn away from the use of film, Lyra Research Inc. projects the digital processing market to reach $7 billion by 2005. Market research provides insight into the future market viability of each printer segment. It should be noted that while wholesale fulfillment remains a lower cost option for the consumer, few select this option to develop their digital prints.
The market breakdown is as follows:

Market	MiniLab	Kiosk	Home Printer
CURRENT	6.00%	1%	82%
FUTURE	High Growth	Decrease	Stiff Competition

Figure 5-8: Digital Printing Platforms[55]

- *Home Printer*: Kodak has announced plans to enter this market segment. Given the large number of competitors in this market segment, skeptics question how Kodak's new product will provide competitive advantage. The firm will have to create an innovative product that delivers to consumers a low cost – high quality product.
- *Kiosk*: Kodak dominates this market segment with 23,000 kiosks in the marketplace. Analysts predict that this market niche, currently accounting for a very small segment of the market (approximately 1%) will decline in future months as consumers turn to other print options.
- *Mini-Lab*: Market share of this product is expected to increase from 6% to 32% by 2005. The Mini-labs, with an estimated retail price of $100,000, have the capacity to print up to 2,000 photos an hour. In March of 2003, Kodak had 100 Mini-labs in place while Fuji

had placed 5,000 in the market. Fuji with 60% control of the Mini-lab market has already made partnerships with both Wal-Mart and Walgreen (these two partnerships account for 40% of the total market). Kodak lost significant market share when their partnership with Gretag, a German imaging company, filed for bankruptcy in 2002. The company was licensed to make the image engine, while Kodak would provide the software piece. Kodak was forced to scramble and select Noritsu as a new partner with which to collaborate.[49] The Mini-lab example illustrates a classic 'hold-up' problem. This case represents the standard argument: Without strategic control of the image engine Kodak will have great difficulty competing in the digital equipment realm.

5.4 Kodak Professional

In August of 2003 Kodak Professional, also referred to as KPro, merged with the Consumer Imaging line of business. The analog value chain is very similar to the Consumer Imaging traditional analog chain. Traditional value is found in the camera design and assembly. Kodak's profit value in this analog chain is in the consumable output, the film purchase and development process. Similar to the other analog value chains, a large percentage of the profit margin is reliant on the equipment driving the output consumable sales.

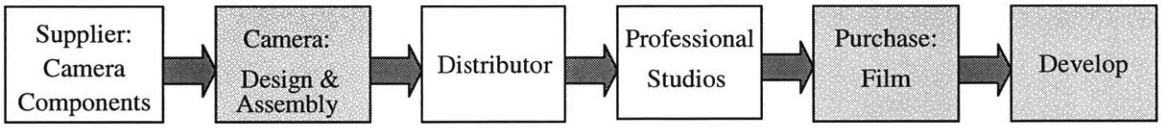

Figure 5-9: KPro Analog Value Chain

In the digital value chain the digital camera is a critical. While the digital camera plays a major role in helping to drive the sale of output consumables, the percentage of consumable sales in this chain is significantly smaller in percentage when compared to the analog chain. Rather than print an entire roll, studios have the capability to more selectively choose images for print. Subsequently, consumable sales are vastly lower. Analysis of Kodak's value proposition in the digital value chain will highlight value in the camera design and assembly.

There are four distinct print platforms for the digital high-end camera: (1) The Digital Color System, (2) LED Printer, (3) Thermal Printers, and (4) KPDM. The Digital Color System creates studio portraits on thermal paper. The LED Printer is another high-end printer; the printhead for

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[49] Keenan, F., "Big yellow's Digital Dilemma," Business Week, March 24, 2003, p. 80.

this piece of equipment is a MEMS device. There are a number of different thermal printers available that are both Kodak developed and OEM. In summary, there is an image engine contained both within the camera and all of the print platforms.

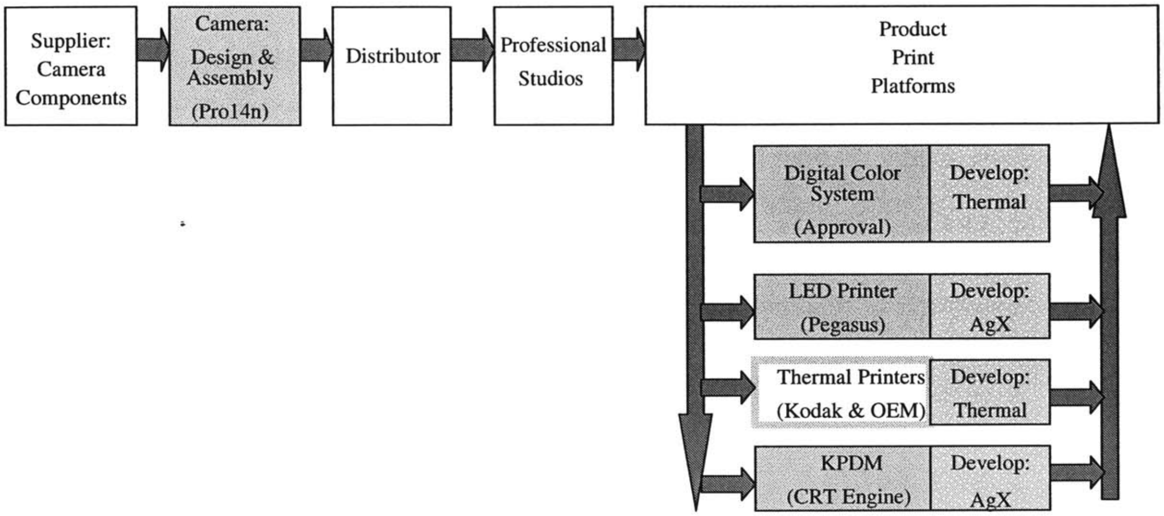

Figure 5-10: KPro Digital Value Chain

Similar to the Consumer Imaging value chains, as the firm transitions into the digital marketplace Kodak's value proposition shifts from the output consumables to the digital equipment. In order to compete in this realm Kodak can't rely solely on their digital signal processing capability. To optimize their image processing capability, the firm needs to have strategic dynamic control of their image engines. This in turn will ensure consumers the highest product quality to leverage Kodak's image processing capability.

5.5 Document Imaging

In the digital value chain for Document Imaging the value is extracted from two spheres: (1) the scanner equipment and (2) Kodak enabled software. Kodak designs scanners for four market segments, which include high volume, middle volume, low volume, and departmental. The specifications for each segment in terms of speed and resolution are highlighted below.

	High Volume	**Middle Volume**	**Low Volume**	**Departmental**
Speed (ppm)	120-160	57-85	50-75	10-25
Resolution (ppd)	up to 40,000	up to 15,000	up to 5,000	up to 1,000

Figure 5-11: Scanner Market Segments

Division A has assembled the image engines for the high and middle volume scanners. Today the market is saturated for both of these market segments. The current high market growth area is in both the low volume and departmental volume; both of these segments are considered more of a commodity item. While the high and middle volume segments require core manufacturing competencies for assembly (described in Chapter 3), the low and departmental segments do not require these same high-end competencies.

The high-end scanners are represented in the value chain illustrated below.

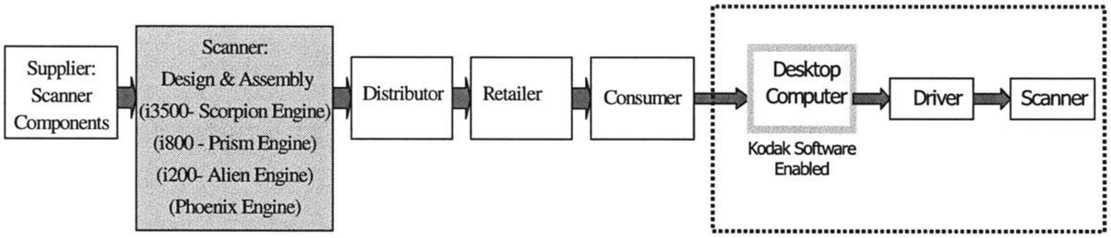

Figure 5-12: DI Digital Value Chain

It should be noted that in the digital Document Imaging value chain there are no consumables. The scanners' image engines are critical in order to maintain strategic dynamic control. In addition, Kodak software is enabled through the professional/consumer desktop computer. Again in order to optimize the software capability, strategic control of the equipment is critical.

5.6 Entertainment Imaging

The Entertainment Imaging value chain is an integrated analog to digital value chain. To begin, the directors take a photo at which time the luminary function is enabled for previewing the image. The Kodak enabled software contains several different preview modes including: (1) Monitor Calibration, (2) Cinematographer View, (3) Colorist View, and (3) LabView. Once the studio, director, or cinematographer views the image, they will determine whether the image should be retaken or captured on analog film. After the image is placed onto film, it is again scanned into digital format using the Spirit 1 or Spirit 4K scanner. This serves as another preview option that has saved sufficient time in the value chain. If the image passes both the luminary and scan milestones it will be placed first on ECN negative film, followed by an intermediate film, and lastly final print film. At this juncture a watermarking is placed on the final print film to ensure that tampering will not occur. A high-speed recorder is then used to convert the image from analog to digital format. Finally the digital image is sent to the distributor or studio together with the formatted film for archival purposes.

There are three output channels in the Entertainment Imaging value chain: TV, Motion Picture Analog, and Motion Picture Digital. For TV the analog or digital captured images can be converted to HDTV, SDTV, VHS or DVD. In the motion picture analog, the analog projector is utilized to display the image. For the motion picture digital, the digital projector is used. In addition, Kodak has developed the Kodak Digital Cinema System. The system's primary function is to convert all of the commercials and/or previews that appear before the cinema movie from analog to digital format in order to improve image quality.

Kodak's value in the upstream portion of the value chain is therefore in the luminary and scanner preview functions, and in the high-speed recorder. Similar to the other value chains examined, the output consumable sales have significantly decreased. This can be directly correlated to the luminary and scanner preview functions that have enabled image viewing before final print. Image engines are found in the scanner, high-speed recorder and digital projector. Here again, it is critical for Eastman Kodak to sustain strategic dynamic control of the image engine in order to maintain market competitive advantage.

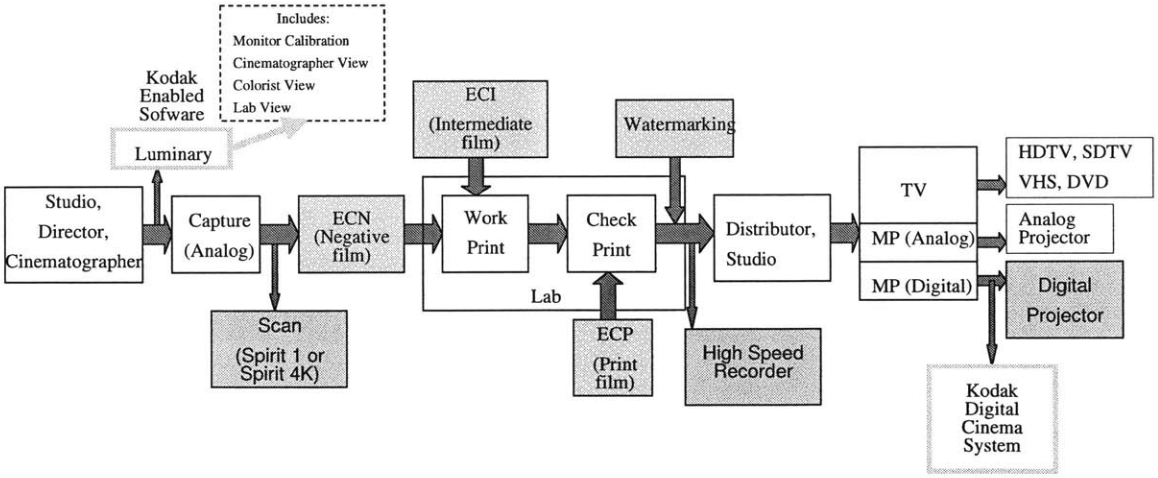

Figure 5-13: EI Integrated Analog/Digital Value Chain

5.7 Summary

Close examination of the lines of business value chain maps illustrate the same findings for each unit. The business strategies and value chains illustrate a lower reliance on consumables. The value chains highlight the importance of image engines as 'enablers' to optimize digital image quality. The integration of image processing systems for digital equipment is therefore closely reliant on image engine performance. Eastman Kodak's operations strategy must profitably support and align with this shift in business strategy. The image engines highlighted are all low volume potentially high mix assemblies, with the exception of the display and home printer in the digital value chain for Consumer Imaging. An operations strategy needs to profitably support and align with this shift in business strategy. In order for Eastman Kodak to maintain market competitive advantage, it is absolutely essential for the firm to sustain strategic dynamic control of their image engines.

CHAPTER SIX: STRATEGIC OUTSOURCING

6.0 Introduction

> *"Through outsourcing, companies can now dump operational headaches and bottlenecks downstream, often capture immediate cost savings, and avoid labor conflicts and management deficiencies...But in the race to hand over capital-intensive manufacturing assets to outside suppliers, companies may be ceding the very skills and processes that have distinguished them in the marketplace."*[50]

A study conducted by Dun & Bradstreet in 2000 concluded that 20-25% of all outsourcing relationships resulted in failure within the first two years, and that 50% had resulted in failure within five years. The survey further reported that suppliers were unsure of their exact relational function to the partner firm, and consequently resulting costs and services provided were much higher than initially anticipated. Rather than assume outsourcing the corporate panacea, corporations need to critically assess the ramifications of the resulting sourcing decisions on future firm performance. For example, a McKinsey study determined that the auto industry's total operating profits would double by simply increasing firm strategic dynamic control over the value chain.[51] The following cultural behaviors are a few of the 'decision traps' that can lead to loss of firm competitive advantage[52]:

- *Shortsighted Thinking*: Characterized by gathering data and quickly reaching conclusions without first developing a framework by which to consider the long-term ramifications of current decisions.
- *'Shooting from the hip'*: Distinguished by failure to develop a systematic approach to collecting key information necessary for the decision-making process, resulting from overconfidence in current assumptions.
- *Complacency*: Illustrated by failure to lead the decision-making process based on the assumption that other colleagues can be relied on to make good decisions.

This chapter provides an examination of a few strategic sourcing frameworks. Careful assessment of these models will help firms to avoid the cultural behavioral decision traps that can lead to loss of firm competitive advantage.

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[50] Doig, S., Ritter, R., Speckhals, K., and Woolson, D., "Has Outsourcing Gone too Far?" The McKinsey Quarterly, no. 4, 2001.

[51] Doig, S., Ritter, R., Speckhals, K., and Woolson, D., "Has Outsourcing Gone too Far?" The McKinsey Quarterly, no. 4, 2001.

6.1 Fine's Sourcing Framework

Professor Charles Fine developed the sourcing framework illustrated below in order to provide a methodology by which to assess the sourcing decisions for each value chain element. The framework involves both a qualitative strategic model and a quantitative economic model. The qualitative segment examines (a) customer importance, (b) technology clockspeed, (c) competitive position, (d) supplier capability, and (e) architecture. The quantitative segment assesses (a) costs, (b) assets, (c) revenues, and (d) competitive cost structures. The data gathered from the strategic value added and economic value added capabilities are then considered together to determine the appropriate recommendations: (a) sourcing, (b) investment, (c) architecture, and/or (d) alliance insights.

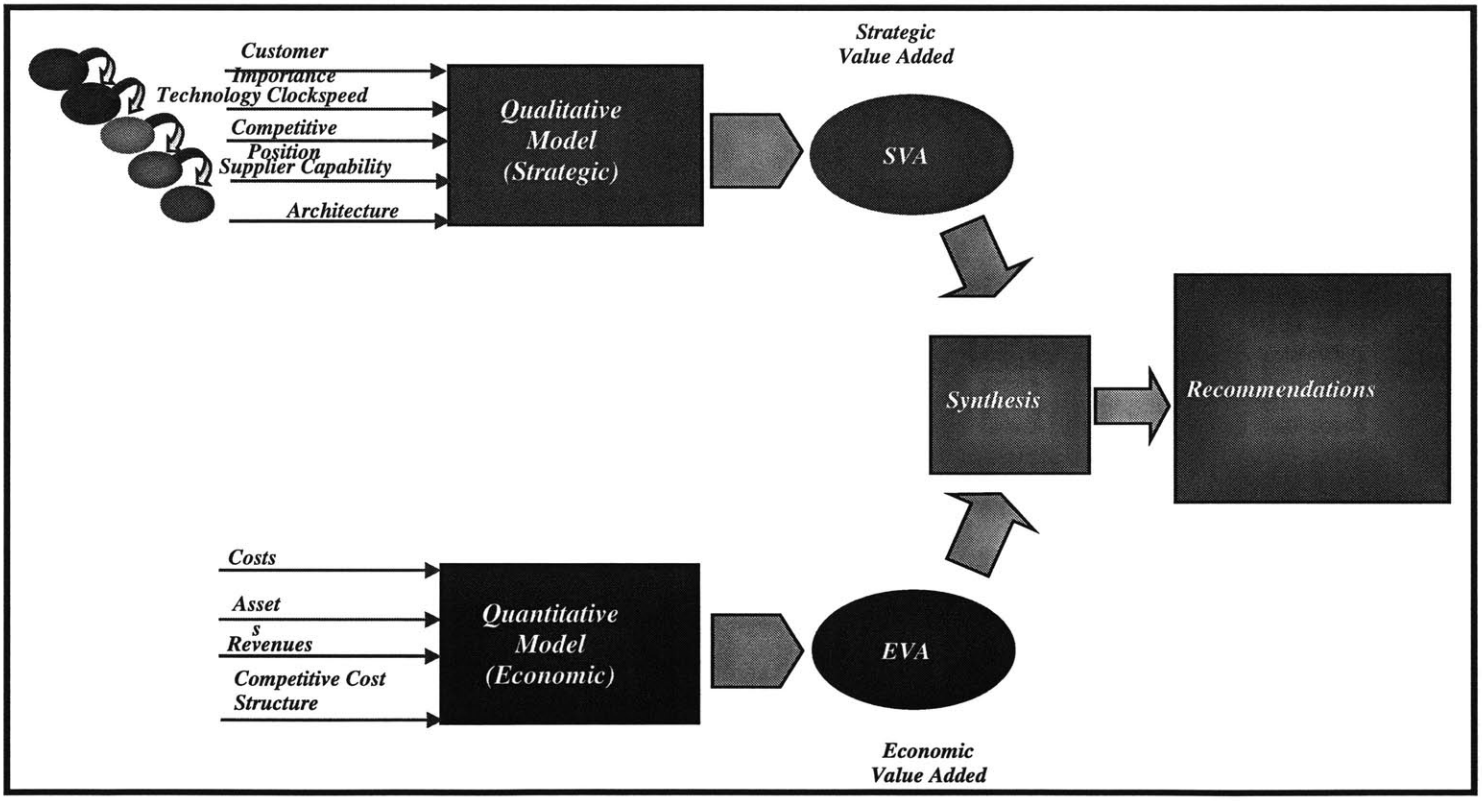

Figure 6-1: Fine's Sourcing Framework[53]

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[52] Greaver, M., Strategic Outsourcing, New York: American Management Association, 1999.

6.1.1 Customer Importance

Customer importance examines the effect of sourcing decisions on customer preferences or buying patterns. Customer importance data are critical for determining the design features for which customers are willing to pay a premium purchase price. To quantify consumer subsystem level preferences, consumer tastes data must first be gathered on product performance characteristics, and then correlated to the appropriate product subsystem.[54]

In order to maintain Kodak's highly regarded brand name, the corporation must continue to satisfy customers. To illustrate the importance of brand recognition, consider both Kodak's high-end professional camera and consumer one-time use camera. In the high-end segment there are photographers who purchase Kodak's digital camera for its exceptional image quality, ease of use, and reliability. This buyer group has no preference for whether the CMOS imager chip was made internally or at an OEM. This buyer segment is concerned with the final package, the ability to create and capture a crisp, beautiful image. The exceptional image quality, however, is a result of the sub-micron alignment of mechanical systems, image quality testing and verification, and image system optimization of the imager. Subsequently, these manufacturing competencies can be directly correlated to high customer preference for this product.

The buyer segment purchasing the one-time use consumer camera is not purchasing product for the highest-level image quality. Without significant research in this area, buyers are primarily concerned with camera functionality, such as lighting and robustness. In this example, there aren't any subassemblies directly linked to customer preference. Therefore, for this low cost – low performance product, customer importance is low.

Analysis for all Kodak's low-volume, potentially high mix digital equipment would illustrate high customer importance. Considering another example, for the computer radiography systems, radiologists are purchasing the equipment for its exceptional image quality, added digital signal processing intelligence and integration to the PACS system. The subassembly described earlier in Chapter 4, the Mini-Fast Scan, provides high definition image capture as a result of the competency to perform sub-micron laser alignment and laser noise characterization. Hence customer preference for this subassembly is high because it is directly linked to overall product image quality.

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[53] Fine, C., Vardan, R., Pethick, R., and El-Hout, J. "Moving a Slow-Clockspeed Business into the Fast Lane: Strategy Lessons from Value Chain Redesign in the Automotive Industry," July 2001.

[54] Fine, C., Vardan, R., Pethick, R., and El-Hout, J. "Rapid-Response Capability in Value-Chain Design," Sloan Management Review, Winter 2002, pp. 69-75.

6.1.2 Technology Clockspeed

Technology clockspeed provides a methodology to assess how rapidly the underlying technology in a particular value chain segment is changing. The measure of clockspeed examines the rate at which technology for subsystems and products are being transformed. To maintain firm competitive advantage, investment in technological competency development for subsystems and products is essential to align with market demand for rapid innovation or 'fast clockspeed.' Fine discusses Kodak's history in his book *Clockspeed*, highlighting the fast clockspeed required in the transition from analog to digital[55]:

> *"While Kodak started as a relatively fast clockspeed company, its pace of change slowed as two things happened. First, the technology matured. Although new products are continually developed, the basic silver halide technology pioneered in Kodak's early years still drives the vast majority of Kodak's profits in film. Second, as Kodak enjoyed a near monopolistic position in its field, the competitive pressure to operate at a fast clockspeed simply did not exist. No matter what the people at Kodak did, it seemed that they always made enormous profits. But the winds have shifted. The competitive environment looks much different for Kodak in the age of digital everything."*

The value chains highlighted in Chapter 5 illustrate a portfolio of digital products, each dependent on attaining rapid speed to market in order to maintain competitive advantage.

The case study of the digital radiography system highlights the importance of maintaining and enhancing core competencies internally in order to deliver product rapidly to market. Kodak has been dependent on Analogic, a small imaging firm in the Boston area, to integrate and develop the digital radiography system. The external environment suggests that the digital radiography system could prove a cash cow for Kodak. At this juncture, Kodak is going to begin development and integration of the system internally. This will prove a very challenging and costly task for Kodak, in part because of the high competency development funding required and high learning curve necessary for successful commercialization of this product. In retrospect, had Kodak served as the integrators in the value chain during the past few years they would have developed the required core competencies internally. In order to succeed in this market segment, Kodak must overcome these key challenges and prove able to deliver product rapidly to market.

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[55] Fine, C., Clockspeed: Winning Industry Control in the Age of Temporary Advantage, Reading, MA: Perseus Books, 1998.

6.1.3 Competitive Position

Value chain analysis will provide insight into the critical elements necessary for obtaining corporate competitive advantage. When these elements are also of 'high customer importance' and 'fast clockspeed,' these subassemblies or products are potential sources for insourcing. Value chain elements characterized by weak competitive advantage are potential sources for outsourcing.

Porter's Five Forces described in Chapter 2 offer a methodology to assess whether product or subassemblies provide corporate competitive advantage. When using this framework to examine Kodak's low volume potentially high mix image engines for digital equipment, high level analysis indicated the following results:

1. *Threat of Entry*: Medium
    - A. *Capital Requirements*: Medium capital investment costs for new entrants.
    - B *Switching Costs*: High for professional products such as the digital Mini-Lab.
    - C. *Cost Disadvantages*: High learning curves; development and manufacturing competencies are difficult for substitutes to rapidly learn.
2. *Rivals*: High level of competition from corporations including Sanyo, Sony, Fuji, etc.
3. *Substitutes*: High threat for substitution from disruptive technology.
4. *Buyer Power*: Medium
    - A. High switching costs for professional segments, low for consumer segment.

        (For example, an HMO may purchase 10 computer radiography machines for a hospital; the switching costs for this equipment are high. The entire support infrastructure including the PACS system would require reconfiguration).
    - B. Buyer has access to 'full information' to ensure buyer favorable prices.
5. *Supplier Power*: Medium
    - A. Suppliers for image engine components present a low threat of forward integration and high threat of 'hold-up.' (For example, FillFactory supplies Kodak with the CMOS imager chip for the Pro14n high-end camera. FillFactory doesn't have the capability to forward integrate in the value chain; however, they do hold the threat of potential 'hold-up' of camera imagers.)

This oversimplified analysis illustrates a relatively *medium* level of image engine competitive advantage. The threat from rivals and product substitution (resulting from disruptive technology) is high, while the threat of new entrants, supplier power, and buyer power is medium.

Comprehensive competitive market analysis of image engines must be performed in order to make future strategic sourcing decisions.

Image engines are thus characterized by medium competitive advantage. However, in cases where the decision to make or buy value chain elements are characterized by *weak* competitive advantage, the following factors should be considered[56]:

- *Factor Cost Advantages*: Typically cost advantages are derived from lower personnel wage rate. As an example, in the automotive industry supplier cost advantages are approximately 30 to 40 percent lower relative to OEMs.
- *Economies of Scale*: The price of doubling the output is less than the cost of doubling the input.
- *Productivity*: This measurement is taken by adding the total number of direct and indirect number of hours per product plus the number of productive hours, all divided by the total number of employees.
- *Potential Cost Optimization*: Optimized cost logistics, total warehousing, transportation, and setup costs for both manufacturer and supplier.

6.1.4 Supplier Capability

Another important metric in assessing the make versus buy decision is in measuring the relative strength of the existing supply base. Given the scenario that a value chain element was outsourced, the leverage capability that a supplier could potentially control can be determined by the strength and size of the supply base. For example, when there are several suppliers with identical capabilities, there is a greater probability the product or subassembly represents a weak source of strategic competitive advantage (i.e. commodity item). In comparison, when only one supplier is in existence, there is a higher potential for the supplier to threaten to use the asset in a way that is not optimal for the equipment manufacturer. Under this non-integration model (it is implicit that the manufacturing firm does not own the upstream supplier) the upstream supplier can 'hold-up' the firm. For example, the supplier can demand renegotiations after investments have been made.[57]

Study of Kodak's image engines with respect to supplier capability has not been conducted at this time. Benchmarking studies have to be performed in order to assess external suppliers' manufacturing capabilities.

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[56] Bruck, F., "Make versus Buy: The Wrong Decisions Cost," The McKinsey Quarterly, no.1, 1995, pp. 28-48.

[57] Gibbons, R., Lecture Note 2: Hold-Up May Be Your Friend, Course 15.903, MIT Sloan, Spring 2003.

A study conducted in 2001 examined the recent trends in corporate manufacturing strategies. This particular study surveyed 328 manufacturing firms of various sizes, with gross annual sales ranging from $1million to $10 billion. The results illustrated that approximately 48% of the respondents "expressed concerns about single sourcing." The issues that were raised by respondents included increased prices, late delivery, and reduced quality.[58]

6.1.5 Architecture

Architecture can be defined as either integral product architecture or modular product architecture. Integral product architecture "exhibits close coupling among the elements of the product", whereas a modular architecture "features separation among a system's constituent parts where standard interfaces make the exchange of parts relatively simple."[59]

Kodak's image engines exhibit a high degree of modularity. In theory the subsystem interfaces are highly standardized early in the product commercialization process. In order to rapidly ramp-up production and deliver product on time, Kodak is beginning to focus efforts on improving the commercialization process. Product platforms provide one way in which to improve the image engine commercialization process. This topic is the focus in Chapter 7.

6.1.6 Strategic Value Summary

Kodak's strategic competitive advantage depends on the firm's capability to rapidly develop and commercialize product. Kodak's future in digital equipment is reliant on whether the firm can continue to satisfy consumer preferences, providing consumers with high performance – lower cost products. The analysis of image engine strategic value has shown that while the market may provide a few OEM suppliers who possess the capability to manufacture these subsystems, the dependence for knowledge on suppliers makes this option extremely unattractive. Kodak's future in digital equipment is reliant on whether the firm can continue to satisfy consumer preferences while at the same time continuing to enhance and further develop their core competencies in order to maintain competitive advantage.

Only through the insourcing of image engine concept development and pilot production ramp-up will the appropriate learning curves be achieved. Image engine core competencies need to be maintained, enhanced, and leveraged in the future, potentially through an image engine platform,

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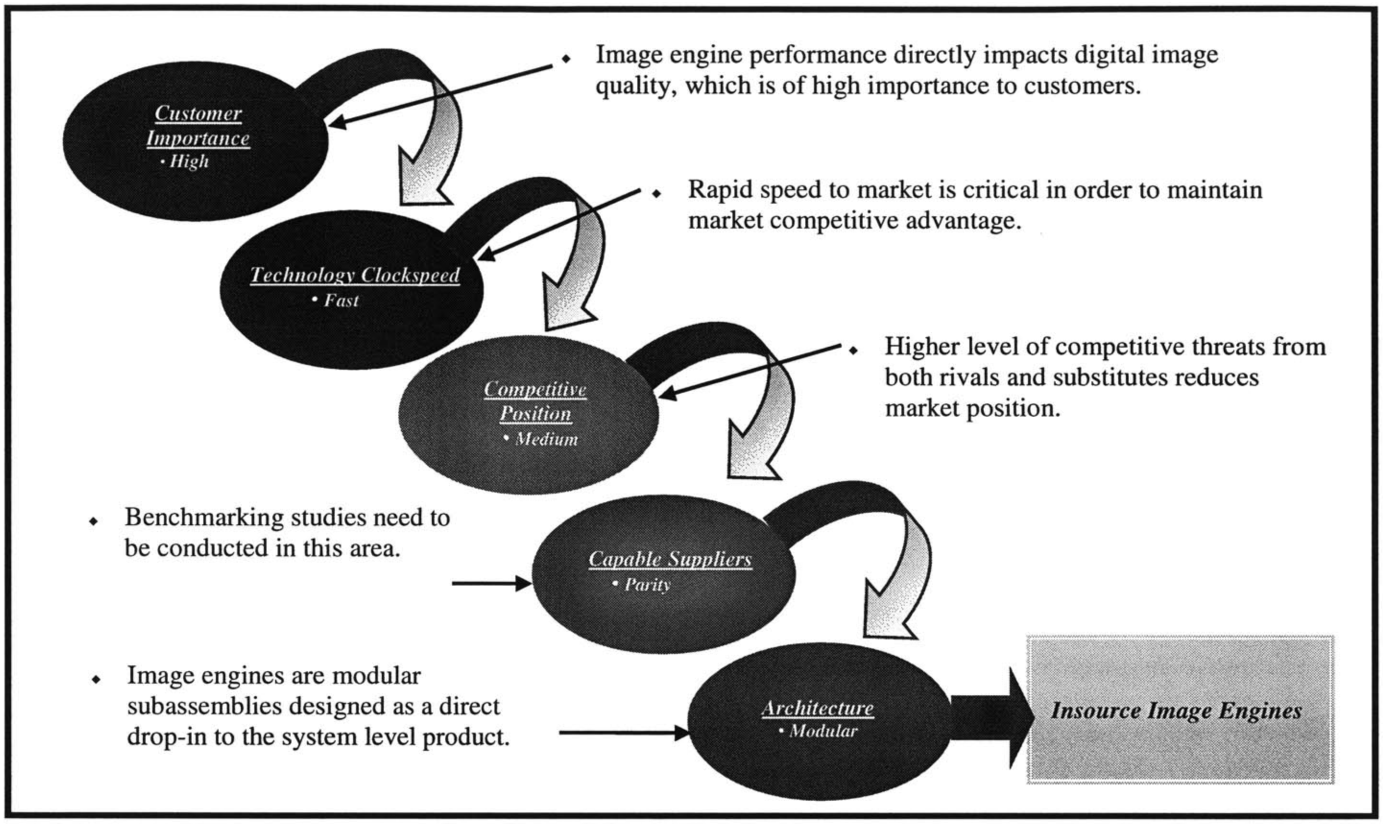
[58] Park, H., Reddy, C., and Jurn, I., "Sourcing Strategies of Manufacturing Firms: Transaction Cost Implications," Mid-American Journal of Business, vol. 16, no.2, 2001, pp. 11-19.

[59] Fine, C., Vardan, R., Pethick, R., and El-Hout, J. "Rapid-Response Capability in Value-Chain Design," Sloan Management Review, Winter 2002, pp. 69-75.

in order to enable the future growth of digital equipment. Figure 7-2 provides an illustration of this strategic summary.



- Image engine performance directly impacts digital image quality, which is of high importance to customers.
- Rapid speed to market is critical in order to maintain market competitive advantage.
- Higher level of competitive threats from both rivals and substitutes reduces market position.
- Benchmarking studies need to be conducted in this area.
- Image engines are modular subassemblies designed as a direct drop-in to the system level product.

Figure 6-2: Adapted from Fine's GM Powertrain Project[60]

6.2 Economic Value Analysis

The financial figures were extremely difficult to obtain from the lines of business. The figures that were obtained remain proprietary to Eastman Kodak. Hence it is only possible to present the general findings from the economic value analysis that was conducted for purposes of this project.

Due to the significant overhead that Division A is forced to incur, the manufacturing costs are significantly higher relative to outside OEMs. In evolving from a vertical to a horizontal firm, the Lines of Business at Kodak have been given the freedom to determine their own sourcing strategies. Given this environment and Division A's current cost structure, the Lines of Business have not considered it optimal to select Division A to manufacture a majority of the image

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[60] Fine, C., Vardan, R., Pethick, R., and El-Hout, J. "Moving a Slow-Clockspeed Business into the Fast Lane: Strategy Lessons from Value Chain Redesign in the Automotive Industry," July 2001.

engines that contribute to product competitive advantage. Given this choice the Lines of Business have selected the lower cost option such as Kodak China or outside OEMs.

One potential plan that could make the Division A cost structure more competitive would be to create a new structure, establishing the division as a profit center. This new structure may provide more incentive for the Lines of Business to manufacture image engines internally. The following quote highlights the decisions that must be considered when a new structure is being explored as a feasible solution.

> *"Its performance must satisfy the criteria of factor cost, economies of scale, productivity, and design to cost. In-house manufacturing may measure up to suppliers only if the production divisions concerned are spun off as profit centers, where possible with their own design and development departments – becoming, in a sense, suppliers themselves."*[61]

In order for a manufacturing division to perform well as a profit center the following metrics need to be examined[62]:

- *Productivity*: Measurement of inputs ÷ outputs
- *Quality*: Measurements of waste and rework
- *Timeliness*: Measuring on-time delivery
- *Cycle Time*: Total manufacturing build time – from start to end.
- *Utilization*: Time invested in specific activity ÷ total time available
- *Financial*: Specific financial metrics, for example EVA

Another source Christensen recommends a spin-out organization in cases when a disruptive technology requires an alternate cost structure or when the current disruptive opportunity is negligible relative to the mainstream organization.[63] These are just a few of the metrics that would require assessment to determine the feasibility of repositioning Division A as a profit center.

6.2.1 Division A Image Engine Portfolio

The diagram below provides an illustration of the Division A image engine portfolio. The pie charts are representative of each product's total Cost of Goods Manufactured (COGM). The section highlighted in red signifies the percentage of the image engine to overall product COGM. The y-axis is representative of product cost, while the x-axis represents image engine complexity.

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[61] Bruck, F., "Make versus Buy: The Wrong Decisions Cost," The McKinsey Quarterly, no.1, 1995, pp. 28-48.

[62] Greaver, M., Strategic Outsourcing, New York: American Management Association, 1999.

[63] Christensen, C., The Innovator's Dilemma, Boston, MA: Harper Business Essentials, 2000.

With the exception of those image engines for Products a and b, all of the image engines are high complexity subsystems.

The manufacturing skills and resources required for assembly, test and verification of these image engines are encompassed in the manufacturing core competencies (detailed earlier in Chapter 3). These image engine manufacturing competencies provide a strategic dynamic control through learning faster than the competition, thereby avoiding dependence on other players in the value chain for knowledge and the resulting profit. In addition, the competencies enable the firm to recognize and value potential growth opportunities. These resources can be leveraged with other programs without the time and cost penalties associated with competency renewal. Therefore, the image engines that fall into the category of high complexity should not be externally sourced, but rather developed internally.

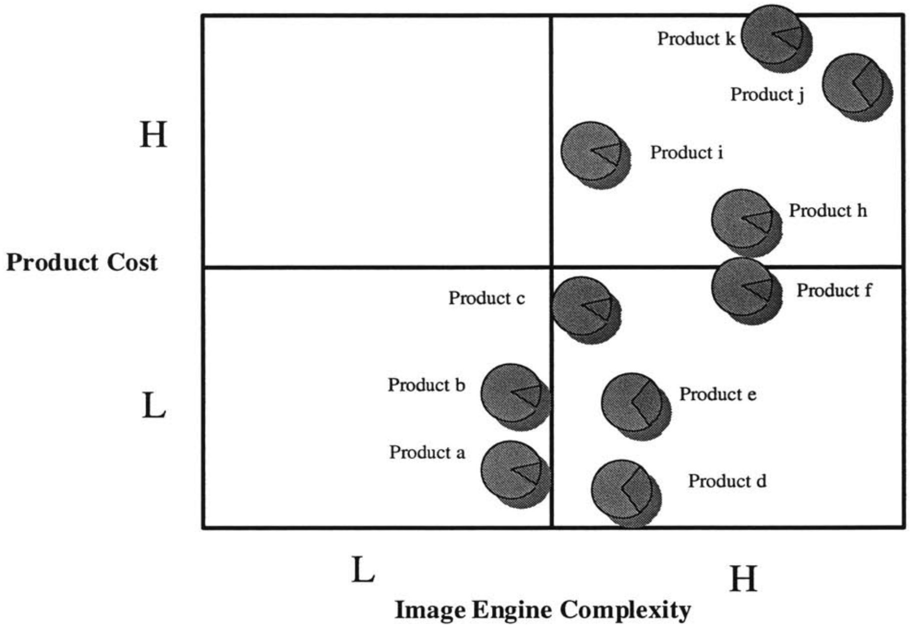

Figure 6-3: Division A Image Engine Portfolio

6.3 Examining Outsourcing Dependence

A study conducted by the Employment Foundation in 1997 indicated that in 75% of the cases where labor costs were critical in the decision to outsource, a capacity or knowledge constraint was also indicated.[64] Figure 6-4 provides an additional framework for assessing the sourcing decision.

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[64] Deavers, K., "Outsourcing: A Corporate Competitiveness Strategy, Not a Search for Low Wages," Journal of Labor Research, vol. 18, no. 4, 1997, pp. 503-520.

This figure is based on the concept of dependence defined by two classifications:

- *Dependence for Capacity*: The firm has the capability to manufacture the subassembly or product however elects to extend capacity to a supplier. Factors for this decision may include time, space, and/or money.
- *Dependence for Knowledge*: The firm doesn't possess the internal expertise to make the subassembly or product and is therefore reliant on a supplier for this knowledge.

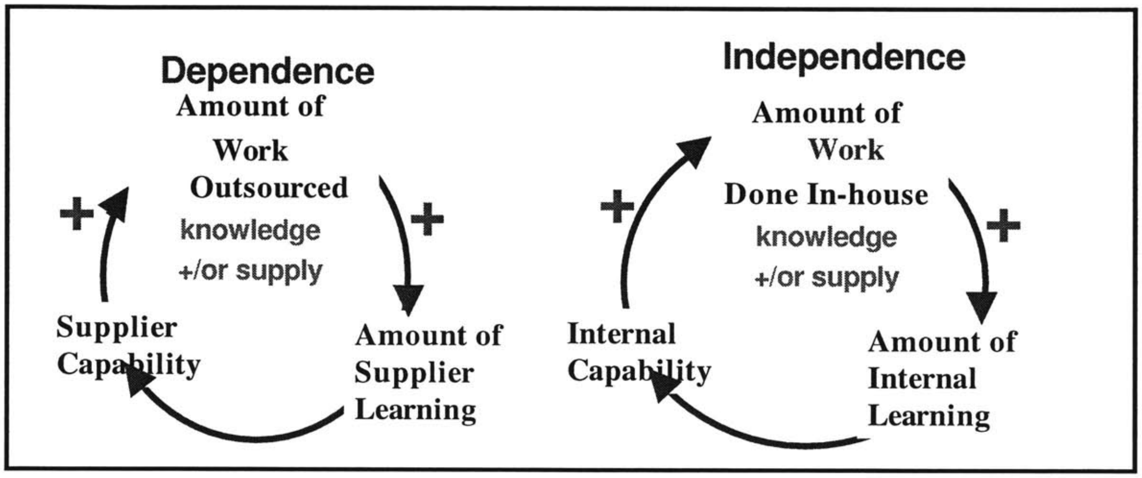

Figure 6-4: Fine's Dependence for Knowledge vs. Capacity[70]

As stated earlier, image engines contribute to firm competitive advantage and hence should be insourced. In this case, outsourcing will only contribute to the failure to build a much needed knowledge base. In a modular product, dependence for knowledge can lead to a "potential outsourcing trap" as the firm relinquishes the ability to continuously improve and develop new manufacturing competencies. In addition, the supplier could possess the ability to backwards integrate, taking away a potentially significant portion of the firm's value in the value chain. Dependence for knowledge in an integral product can result in "the worst outsourcing situation." In this scenario, the firm sacrifices the ability to understand the product integration and component architectures, thereby turning over all source of competitive advantage to the supplier.[65]

In the case of image engines, it is crucial that Kodak position itself as independent knowledge source. The commercialization process will prove far more fluid when the manufacturing process is developed and designed internally. As a result of early design for manufacturing,

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[65] Fine, C. and Whitney, D., "Is the Make-Buy Decision Process a Core Competence?" Logistics in the Information Age, Servizi Grafici Editoriali, 1999, pp. 31-63.

reengineering efforts in the ramp-up and production phases of product development will be significantly reduced.

The focus of Chapter 7 is on the image engine platform concept. The platform provides a framework for Kodak to remain independent for knowledge while dependent for capacity. That is the firm would be able to ramp-up and test product internally thereby enhancing and further developing core competencies. At the same time Kodak would have the capability to implement large scale production efforts externally, taking advantage of lower cost wage rates.

6.4 Alternative Framework

Insinga and Werle offer a framework that provides an alternative model for examining the outsourcing decision. The y-axis represents product potential competitive advantage. The x-axis represents internal firm capability in relation to the competitors.

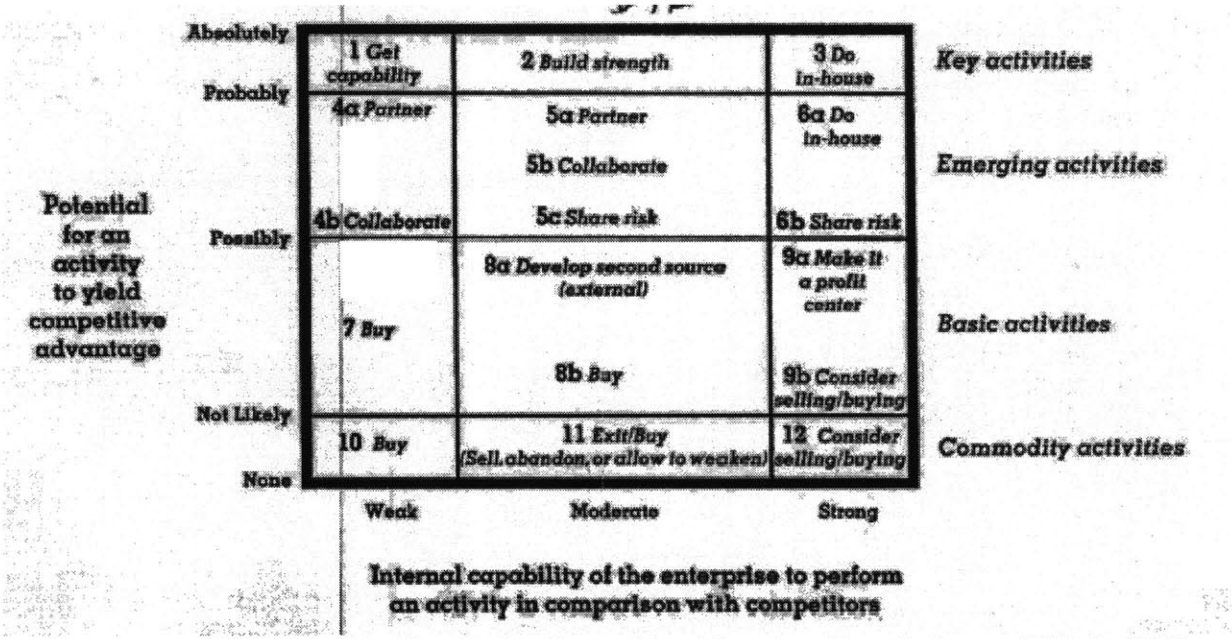

Figure 6-5: Assessing Market Competitive Advantage (from Insinga and Werle, 2000)

An explanation for each cell in the framework is defined below[66]:

(1) *Get Capability*: Competitive advantage for a product and/or subassembly is potentially high with weak internal capability; the firm should build strength in this area, eventually performing function fully in-house.

(2) *Build Strength*: Competitive advantage for product and/or subassembly is potentially high with moderate capability; firm should invest to build internal capabilities.

(3) *Do in-house*: Characterized by absolute competitive advantage and strong internal capability; continue to enhance firm core competencies.

(4) (a) *Partner*: Probable competitive advantage and weak internal capability; firm should move to partner, positioning itself to acquire higher share of ownership in the event that the technology proves successful.

(b) *Collaborate*: Less probable competitive advantage and weak internal capability; firm should strengthen their market positioning and collaborate with another group.

(5) (a) *Partner*: Characterized by moderate internal capabilities and probable competitive advantage; to begin the firm should strategically take a large share of a partnership. As the level of certainty for gaining competitive advantage increases, the firm should begin to move work in-house.

(b) *Collaborate*: Strengthen the firm's market position by collaborating with a more capable group than in Cell 4.

(c) *Share Risk*: Less probable competitive advantage and moderate internal capabilities; risk-sharing enables the firm to invest in higher potential technologies.

(6) (a) *Do in-house*: Emerging technology characterized by potentially high competitive advantage and strong internal capability.

(b) *Share Risk*: Less potential for competitive advantage and high internal capability; maintain degree of active participation in the market and diversify resources into other technologies.

(7) *Buy*: Potential for an activity to yield competitive advantage is unlikely and the internal capability is weak.

(8) (a) *Develop second source*: Potential for competitive advantage is likely and internal capability is moderate; develop second external source for capabilities and continue to leverage and further develop internal capabilities.

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[66] Insinga, R. and Werle, M., "Linking Outsourcing to Business Strategy," Academy of Management Executive, vol. 14, no. 4, 2000, pp.58-71.

(b) *Buy*: Potential to obtain competitive advantage is unlikely; rather than invest resources in internally moderate capability, purchase capabilities from the outside.

(9) (a) *Make it a Profit Center*: Potential competitive advantage with strong internal capabilities; firm should leverage internal capabilities and create a profit center to sell capabilities externally.

(b) *Consider Selling/Buying*: Characterized by unlikely competitive advantage with weak internal capabilities; firm should sell their internal capabilities, reinvesting the profit in developing more strategic capabilities.

(10) *Buy*: Characterized by no potential competitive advantage and weak internal capabilities; the firm should without a doubt purchase these capabilities externally.

(11) *Exit/Buy:* Illustrated by no potential competitive advantage with moderate internal capabilities; exit strategy for firm infrastructure and/or resources in this area.

(12) *Consider selling/buying*: Strong internal capability coupled with little to no competitive advantage; the firm should sell this capability.

As Kodak examines their strategic business plans, to both create and capture value along the value chain, Insinga and Werle's framework can prove a helpful tool for initiating discussion.

6.5 Outsourcing Committee

The frameworks provided in this chapter illustrate the degree of complex analysis that is needed in order to make intelligent strategic sourcing decisions. To maintain future competitive advantage Kodak should develop an internal strategic outsourcing committee to oversee corporate-wide policy decisions for outsourcing. This internal sourcing committee should consist of marketing representatives, supply chain specialists, manufacturing representatives, and technologists. This group's responsibility would include which modules to develop internally, and which to outsource. In creating a sourcing framework, the group would gather and assess data such as (a) level of current internal capability and (b) market competitive advantage, in order to determine whether to acquire, divest, or share risk with external suppliers. This internal sourcing committee would assume responsibility for analyzing and evaluating all future sourcing strategies, and developing carefully constructed plans around each.

6.6 Case Studies

In this section two case studies will be presented which should prove instructive to the sourcing discussion. The case study of Canon provides an example of a firm strategically developing and enhancing internal capability for assembly of low volume-high mix (LVHM) products. The case discusses the firm's sourcing framework for their photocopier assembled in the early nineties. The Hewlett Packard case illustrates the importance of strategic planning and the significance of developing long-term supplier relationships.

6.6.1 Canon

> *"The Company's formula for success as displayed initially in the copier business is synergistic management of the total technological capabilities of the company, combining the full measure of Canon's know how in fine optics, precision mechanics, electronics and fine chemicals."*[67]

Internal investments at Canon are targeted in 'skills of strategic importance.' Canon leverages outsourcing as a means to acquire outside expertise in areas where the firm holds weak competitive advantage and/or weak internal capability. The firm has placed a strong emphasis on tightly controlled inventory management, carefully constructed material and production planning, and close supplier relationships. In 1990, over 90% of the Canon copiers were assembled from purchased parts. The firm had developed long-term supplier relationships and maintained on average two sources for most components. It should be noted that Canon elected to develop and assemble components where they maintained strong manufacturing core competencies and high market competitive advantage. For this case of copiers Canon manufactured the drum and toner in-house.

While dependent for capacity on many suppliers for purchase of components, the firm retained internal knowledge regarding the integration and product assembly process. The company maintained its own in-house pilot production capability to better understand the product technology integration and supplier cost allocation. Canon made the decision to decentralize manufacturing capabilities in order that each assembly facility would focus on one product portfolio or family. The firm leveraged product platforms in order to maintain and further develop products at lower cost and higher quality. Parts commonality between subsequent copier models was approximately 60% for many models.

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[67] "Canon: Competing on Capabilities," Fontainbleau, France: INSEAD, 1992.

Canon and Kodak, while rivals in some market segments, have partnered in developing two joint SLR cameras in years past. Canon provides an excellent benchmarking example for Kodak's low volume potentially high mix image engines. Canon follows several important practices:

(1) *Supplier Relationships*: Long-term relationships are developed. In order to prevent 'hold-up', two supplier sources are maintained for most components.

(2) *Unique Technologies*: In order to maintain competitive advantage, Canon develops and maintains unique technologies in-house.

(3) *Pilot Facility*: The pilot facility ensures that Canon remains in control of the integration and development of their products. In addition, this facility ensures that the firm is only dependent for capacity and not for knowledge.

(4) *Product Platform*: The firm utilizes a platform concept to decrease product cost and time to market.

These are critical practices that Kodak should carefully examine. Implementation of an operations strategy for image engines through a pilot facility and/or platform will ensure that image engine core competencies are leveraged and further enhanced in the future. This topic is the focus of Chapter 7.

6.6.2 Hewlett Packard

The Hewlett Packard (HP) tape drive case provides a sourcing model for a mature high volume product. While the tape drive market is considered a mature industry, tapes still provide an 'economical way to store large volumes of digital data.' Figure 6-6 provides an illustration of the DDS disk drive portfolio. The mechanism, PCA (printed circuit board assembly), and head were all purchased from external suppliers. HP controlled the final assembly and test. A contract manufacturer configured the system after final assembly and test. The end product was then delivered through two channels: (1) HP's distribution center or (2) an OEM.

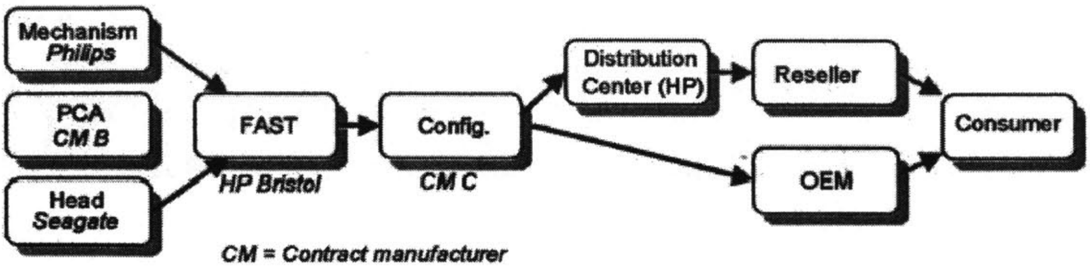

Figure 6-6: HP Supply Chain for DDS Model Ultrium[68]

In 1997 the Bristol, England factory did not possess either the capacity or infrastructure investment dollars for this product. Therefore, the requirements mandated for assembly and configuration of DDS products were no longer feasible in the Bristol facility. Unlike Kodak's image engines, HP's manufacturing core competencies were characterized by *weak* market competitive advantage. Between the years 1997 – 2000 the entire DDS product family was outsourced. At this time, the firm had no general strategic sourcing plan for this product. The following quotation underscores the consequences that resulted from this ill-conceived sourcing strategy.

> *"..(There have been)... three major deals with different generations of DDS products. The relationships with the earlier contract manufacturers were becoming quite difficult due to the limited future. We had hoped to grow the business with the new CM but were having operational problems. The Misumi relationship was working very well, however the overhead to manage all of these various relationships was going through the roof. At this stage we also started to have heated debates between the functions (accountants, supply chain and engineering) about the relative benefits of each sourcing decision."*[69]

HP had unexpectedly high overhead costs as a result of these contract manufacturing relationships. In addition, the firm was expected to help the contract manufacturer solve engineering and assembly issues. To avoid the reengineering problems, HP decided to change its strategy to incorporate the supplier much earlier in the process.

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[68] "Hewlett-Packard: Creating A Virtual Supply Chain (A)," Lausanne, Switzerland: International Institute for Management Development, 2001.
[69] "Hewlett-Packard: Creating A Virtual Supply Chain (A)," Lausanne, Switzerland: International Institute for Management Development, 2001.

The take-away from this case study is that "bureaucracy and unclear accountability render decision making difficult."[70] Supplier management and development is critical in order to lower cost and deliver product on time. Further this case underscores the importance of an outsourcing committee to oversee corporate-wide policy decisions for sourcing. Without the initiative and direction from top leadership to develop and maintain long-term supplier relationships, divisions will continue to follow a series of disjointed strategies.

6.7 Summary

Image engine performance directly impacts the level of digital image quality; hence strategic control of this module is critical in order to maintain firm competitive advantage. Kodak's strategy dynamic control of image engines would allow the firm to continuously enhance internal learning. This avoids dependence on other players in the value chain, resulting in increased profits. In addition, strategic dynamic control of image engine core competencies would provide Kodak with a baseline to recognize and value potential growth opportunities. Image engine core competencies must be maintained, enhanced, and further developed in the future. Development funding is required to ensure the continued growth of the internal learning cycle, paramount for maintaining market competitive advantage.

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[70] "Hewlett-Packard: Creating A Virtual Supply Chain (B),"Lausanne, Switzerland: International Institute for Management Development, 2002.

CHAPTER SEVEN: PRODUCT PLATFORMS

7.0 Introduction

> *"In a world of rapid flux, organizations must change their priorities from a traditional focus on planning, control, and managed growth, to emphasize speed, innovation, flexibility, quality, cost and service."*[76]

Analysis of Eastman Kodak's products containing image engines reveals a fragmented process in dire need of radical changes. The only methodology by which to improve product performance requirements, reduce image engine costs and increase speed to market is by examining the end-to-end commercialization process. The commercialization process defines the systematic flow for how work is completed and thereby implemented to create customer value. This defined process shapes the scope of related job functions, which in turn solidifies the organizational structures and management systems required. These systems are instrumental in defining the organizational culture such as the attitudes, beliefs and cultural norms.

There are no simple solutions to change this radically complex product commercialization process. The following three driving forces can serve as a catalyst for driving motivational urgency and corporate change:

- *Customers*: Large range of substitute products
- *Competition*: High threat of global competition
- *Change*: Rapid rate of technological change

In a highly competitive marketplace where the technology clockspeed is rapid and customers may choose among a range of substitute products, the firm must remain continuously vigilant in examining and analyzing its commercialization. The firm must remain in a state of preparedness to realign the commercialization process as needed. Successful process changes rely on thorough strategic planning and implementation efforts. These changes also require coordination by an individual or group who serves as a corporate champion for these efforts. This corporate champion must ensure that efforts are facilitated and supported.[71]

This chapter focuses on product platforms as a means to improve image engine performance requirements, reduce costs, and increase speed to market. In addition, this chapter provides an examination of organizational learning and the importance of product value innovation and disruptive innovation as a means to ensure efficient and successful strategic planning.

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[71] Hammer, M. and Stanton, S., The Reengineering Revolution, New York: Harper Collins, 1994.

7.1 Commercialization

Research performed on product development and commercialization has illustrated that product failure begins with the misalignment of customer demand and initial product definition. While managers have difficulty forecasting customer needs and determining the appropriate market segment, following the current market too closely can also have dire consequences. Incremental product improvements along current product performance curves can potentially leave too few resources to examine disruptive technologies. Too frequently firms will focus their efforts solely on 'outbound' promotion or selling activities rather than on organizing and assessing market information into 'actionable commercialization steps'.[72]

One of the largest challenges facing managers in research today is the ability to produce potentially profitable products in much shorter clockspeeds. This has placed increased pressure on both the research labs and the business units to produce product at increasingly faster rates. Historically Kodak has been the world leader with first-class research teams; however; there seems a disconnect when attempting to apply these findings to the study of practical applications. Too often those products that are based on research efforts reach the market with cost over runs and behind schedule.

Many firms have reacted to the inability to commercialize product from inventions developed in the research laboratories by simply decreasing investments in the research labs. Corporations have instead turned to universities and external sources for knowledge. As illustrated earlier in Chapter 2, this practice can lead to a firm's demise due to the lack of internal capability and competency development. Root-causal analysis will illustrate that failure to commercialize product is centered in part on poor information flows between the research lab and Lines of Business.

7.1.1. Hewlett Packard

At a time in history when research lab funding is shrinking, Hewlett Packard (HP) has heavily invested increasingly larger amounts of funding in their laboratories. From 1993 to 1994, funding increased by a whopping 12%. The firm has three research labs, one located in Palo Alto, California focused on computer research and measurement, and another in Bristol, England centered on multimedia and personal appliances. In addition, they have a smaller lab in Japan dedicated to research in physics and semiconductors.

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[72] Rosenbloom, S. and Spencer, W., Engines of Innovation, Boston, MA: Harvard Business School Press, 1996.

Successful commercialization of products has been much in part due to the well-established information flow and knowledge sharing between the research labs and divisions. HP has worked to centralize their strategy to invest in core technologies. In 1993 the firm set up a council consisting of technologists and marketers from the three central divisions. Members were assigned the task of determining new market segments that would incorporate capabilities from all three divisions (measurement, computation, and computer networking). The council worked to capture the potential synergies across the company's diverse set of technologies and competencies. In the past the firm had devoted 85-90% of its resources to supporting current market niches, while today over one third of the research effort is devoted to determining new business opportunity.

This case study has important implications for Kodak. Similar to HP in the early nineties, Kodak has a technology council. However, it is primarily used for business unit technology road mapping. Since it is focused within each business unit, cross-division competencies are not explicitly developed. In order to optimize the market research capabilities and possibilities, it is strongly recommended that Kodak should implement a group structured similarly to HP's corporate council.

7.1.2. Kodak's Image Engine

The commercialization of Kodak products containing image engines often fail to meet cost, schedule and/or performance requirements. The current image engine commercialization processes are disjointed as a result of undefined information flows, poor knowledge sharing among staff, and/or untimely supply chain planning.

Figure 7-1 seems to have particular application to Kodak's current situation in regard to the commercialization of image engines. The figure illustrates the "chasm of uncertainty," a phrase coined by Meyer and Lehnerd to represent the commercialization discontinuities that threaten a firm's market share. Rather than fall victim to the "tortuous path of product development" characterized by today's realities of "aging product lines, an unclear vision of the future, and an unmanageable complexity of products and organizations," the arch represents conceptual building blocks to achieve "tomorrow's desires." These desires are characterized by "uncontested value cost leadership, robust product families, and prosperous survival." The conceptual building blocks discussed in the next section include platform strategies, composite design, platform teams, and product performance metrics.

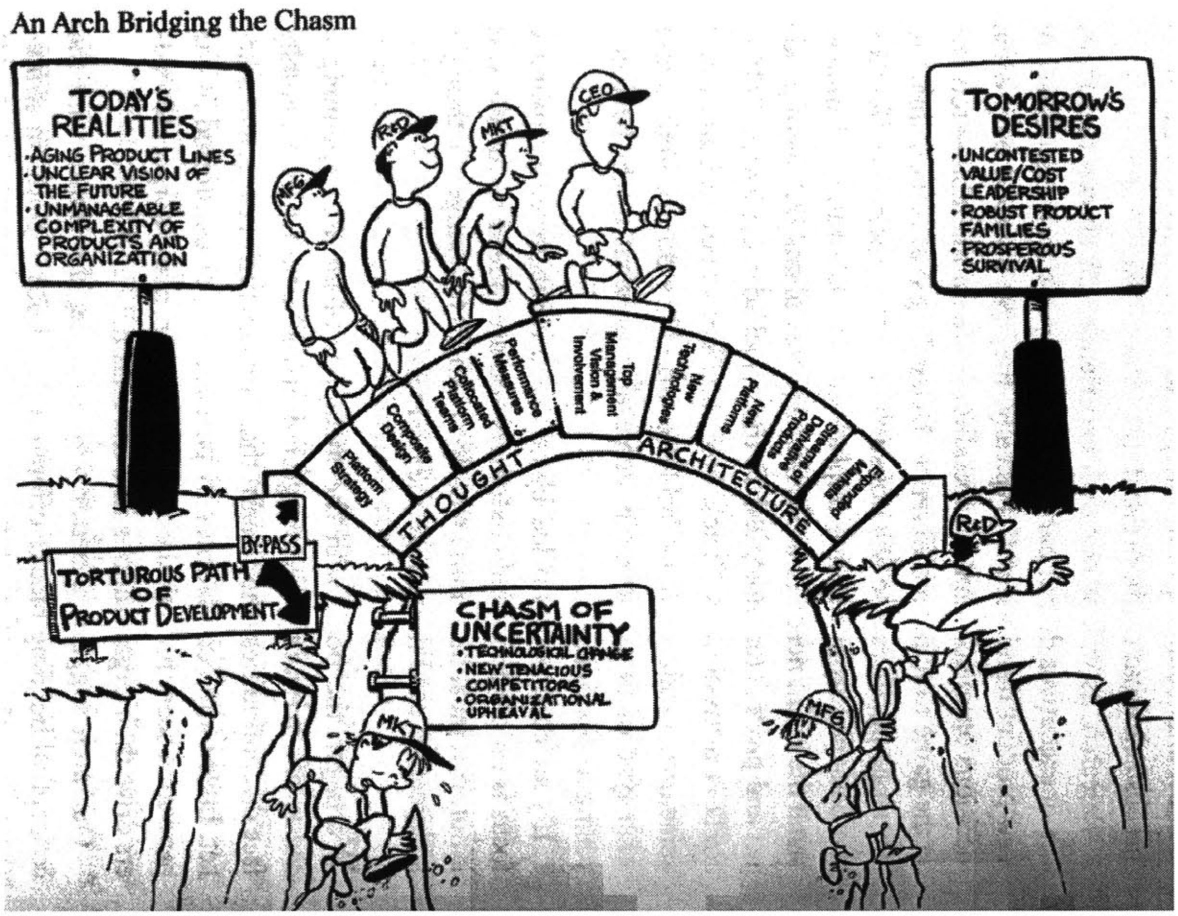

Figure 7-1: Meyer and Lehnerd's Valley of Death[73]

To bridge the 'chasm of uncertainty' and avoid the 'tortuous path of development,' established firms most often take a diversified portfolio approach through mergers and acquisitions. In recent months, Kodak has publicly announced plans to follow exactly this approach in order to more rapidly transition from analog to digital. This approach does not however necessarily prevent a firm from escaping the 'chasm of uncertainty.' As Utterback writes, "A portfolio approach to managing innovation ranks prospects in terms of predictable returns. The result is too often a grab bag of minor process and product improvements considered one by one, each judged on its own financial merits without sufficient consideration given to the long-run strength and competence of the firm in the face of change."[74]

History has shown that mergers and acquisitions oftentimes have disappointing results. Established firms seeking innovative or disruptive technology often purchase smaller entrepreneurial firms to add to their portfolio. Integration of the purchased technology can prove

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[73] Meyer, M. and Lehnerd, A., The Power of Product Platforms, New York: The Free Press, 1997.
[74] Utterback, J., Mastering the Dynamics of Innovation, Boston, MA: Harvard Business School Press, 1994.

extremely difficult. The real assets of the firm, which Utterback refers to as the brains, leave the company after finding the new corporate culture stifling. The established firm is then owner of an 'empty box.' Consequently, the firm is left without the ability to continuously improve and develop integrated derivative products from the new technology. Utterback states that alliances "are no panacea for the flagging corporate vitality." Instead he highlights, the firm will only succeed through the persistence and commitment of top management to renew the firm-wide corporate strategy and continue internal development.

7.2 Product Platforms

> *"A product platform is a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced."*[75]

Product platforms are of the utmost importance in providing a process by which to successfully transfer knowledge and continuously improve learning cycles based on product models. Currently image engines are designed and developed by each Line of Business independently and 'thrown over the wall' for manufacturing. Kodak has recognized the commercialization of image engines as an area requiring drastic improvement, and consequently is further researching the generation of an Image Engine Platform. There are several advantages to the utilization of a platform concept[76]:

- *Long-term Strategy*: Creation and analysis of all of the current and future roadmaps will provide a systematic tool to illustrate the firm's product strategy. This knowledge can then be used to determine the appropriate manufacturing processes. In addition, the platform can serve as the centralized location for decisions related to production and sourcing of components.
- *Learning Curves*: Platforms should continuously evolve to incorporate new technologies and processes. Therefore knowledge sharing pertaining to the enhancement and further development of product and manufacturing design techniques should occur.
- *Reuse*: Modularization of subassemblies prevents reengineering efforts across products. Platforms should provide the ability to create derivative products at

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[75] Meyer, M. and Lehnerd, A., The Power of Product Platforms, New York: The Free Press, 1997.
[76] Cusumano, M. and Nobeoka, K., Thinking Beyond Lean, New York: The Free Press, 1998.

much lower cost investment, through leveraging new component technologies into existing platforms.

In order for the platform concept to prove a viable firm option, a financial assessment of the following metrics is necessary. First, engineering costs need to be calculated for the approximate amount of reengineering required as a result of redundancy between products. Second, the above engineering costs must be compared to those incurred when developing a platform concept. And third, a thorough assessment of the costs necessary to upgrade the manufacturing facility is required.

7.2.1 Black and Decker[77]

The case study of Black and Decker provides an example of a firm that successfully implemented a product platform for their power tool product family. In the 1970s, the firm was burdened with older product architecture. These products failed to share and leverage design capabilities both within and across market niches. For example, there were more than 100 different motors, each manufactured on different production lines. This, in turn, resulted in substantial manpower overhead.

Black and Decker redesigned all of their major product architectures: tools, drills, sanders, circular saws, and hedge trimmers. The firm created a product platform for motors; the platform consisted of a common universal motor designed with a fixed width and variable length. The variation in the motor length enabled a large range of power from 65W to 650W. The motor platform significantly decreased the manufacturing per-unit motor cost by reducing the production infrastructure to one automated high-volume line.

Implementation of the motor platform brought Black and Decker huge rewards by providing the firm with a large cost advantage over their competitors. Black and Decker leveraged their platform capability to create a number of derivative products. The firm increased their market share in the power tools industry by a whopping 20%, driving many smaller competitors out of the business.

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[77] Meyer, M. and Zack, M. "The Design and Development of Information Products," Sloan Management Review, Spring 1996, pp.43-59.

7.3 Platform Implementation

> *"How CEOs can best encourage product development effort is, no doubt, situational determined. There are no magic pills and no instant cures in the medicine bag of corporate leadership. Nevertheless, management must facilitate the development of the building blocks of the future-- the technologies, processes, materials, and services that will drive the company's platforms and products forward in time."*[78]

While there are far more documented examples of product platforms, the general interpretation of platforms is defined as, "A defined set of common or shared elements and its interface definition."[79] Elements referred to in this definition can apply to a number of different architectures ranging from parts and components, to systems, processes and organizations.

This section provides a guide for platform implementation for all of the defined elements. The section follows an outline provided by Meyer and Lehnerd who have outlined a high-level process that can serve as a guide for implementing product platforms. The defined elements which are highlighted serve as a 'thought architecture' for bypassing the 'tortuous path of product development,' to achieve "uncontested value cost leadership, robust product families, and prosperous survival.' Elements are as follows: (1) Definition, (2) Determination of core building blocks, (3) Design and Assembly, (4) Delivery Plan, and (5) Team Organization. After discussion of these elements, three examples of product platforms are provided with an emphasis on process.

7.3.1 Definition

First the platform strategy is defined according to analysis of appropriate market segments. Each respective market segment is assessed according to the following metrics: (a) current market size, (b) estimated growth rate, (c) the firm's current market share, and (d) leading current and potential competitors. The matrix in Figure 7-2 provides a purely hypothetical image engine map for the purpose of illustrating the power of creating platform modules.

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[78] Meyer, M. and Lehnerd, A., The Power of Product Platforms, New York: The Free Press, 1997.

[79] Suk Suh, E., Platform Architecture: A Two-Level Optimization Approach, MIT ESD, 2002.

	Capture	Write	Display
High Cost	Digital Projector	Laser Marking Engine	OLED
Med Cost	High-end document scanner	Computer Radiography Subsystems	
Low Cost	14n		

Figure 7-2: Hypothetical Image Engine Map

The matrix provides an initial framework from which to assess the modules for the product platform design. Currently Kodak has dozens of niche specific platforms that fail to incorporate full knowledge sharing across technologies.

Ford Motor Company recognized that reorganization of niche-specific platforms would lower cost, raise margins, improve manufacturing technologies, and optimize the transactions with their large supplier-base. Acting on this realization, in 1996 Ford reduced the number of vehicle platforms by one third.

Implementation Strategy: Horizontal Structure. One implementation strategy leverages the platform subsystems and manufacturing processes horizontally across the matrix. For the purposes of this framework all new products are assigned to uniform performance and cost tiers.

Implementation Strategy: Vertical Structure. Another implementation strategy leverages the platform subsystems and manufacturing processes vertically across the matrix. This structure utilizes the same platform across a range of cost and performance tiers. There are two variations for this structure, (a) the initial platform concept is scaled downward to a lower cost and lower performance tier or (b) the initial platform concept is scaled upward to a higher cost and higher performance tier.

In an initial assessment, the second structure seems more feasible after analyzing Kodak's image engines. Kodak's potential platform modules (capture, write and display) incorporate vastly different technologies. However, within certain segments, the manufacturing competencies required across performance and cost tiers are similar. Since Division A focuses on high-end performance digital equipment, it would then seem tantamount to follow and implementation vertical structure that is developing a high-end platform from which to scale down to lower performance and cost products. This would be preferable to the horizontal structure which would dictate that the end platform remain at high-end performance and cost products.

7.3.2 Determining Core Building Blocks

Analysis that is made possible with the utilization of a cross-functional team will aid in determining the core building blocks. The core building blocks should be representative of the firm's core competencies. For example, when examining capture platforms there are three manufacturing core competencies; sub-micron alignment of mechanical systems, image system optimization, and image quality test. (All of these competencies were described in great detail in Chapter 3.) Hence the capture devices illustrate a potential opportunity to develop a process platform for these particular subassemblies.

In order to determine the appropriate product platforms several metrics should be assessed. These include (a) current and evolving customer needs (b) core product technologies, (c) manufacturing processes, and (d) sales channels. The current and evolving customer needs should be measured and incorporated into the development of the platform. For example, if customers were looking for tighter tolerances in the six-axis imager alignment, this requirement would have to be incorporated into the platform development. The core product technologies and manufacturing processes need to be appropriately assessed and the core competencies from each incorporated into the platform. The platform is responsible for serving as a center for both the product technologies and manufacturing processes. It is only in this manner that the firm's core competencies can be maintained and further enhanced. Lastly, the sales channels should be measured to monitor the appropriate channel distributions. These channels will impact both the product and packaging features.

After appropriate analysis these metrics should then be drawn together to serve as a template for determining the platform core building blocks. Once these building blocks have been decided, the team can begin building a composite design.

7.3.3 Design and Assembly

The goal for this stage is to create a product platform with manufacturing processes that are 'elegant in their simplicity, form and function.' In order to accomplish this task, the team must thoroughly understand the customer needs. In addition, the team will require complete knowledge of the firm technology and product roadmaps. Without understanding all the current and future technologies and products, it becomes utterly impossible to optimize the platform. In this project, for example, once the image engines are identified in the product roadmaps, the degree to which manufacturing processes are shared between subsystems will become clear for platform design.

In addition, the team should assess the competitors in each market segment to ensure that the platform concept is targeted at the appropriate market segments and performance-cost tiers. The current market segments must be assessed according to product functionality, cost and quality. The future growth areas must be accurately identified according to the following metrics: (a) current sales volume, (b) current firm market share, (c) total firm and competitors' growth rate, and (d) projected customer needs for each segment. If all of these steps are followed, the design should be functional and efficiently support the development of derivative products.

It should be noted that there are two major categories which are useful in defining customer needs:

- *The first category*: requirements of which customers are aware and able to readily express. Market research firms are proficient at identifying these customer needs through surveying and benchmarking the market segment competitors. Meyer and Lehnerd state that these explicit customer demands will only result in incremental product innovation.[80]
- *The second category*: latent customer requirements. These are the requirements that customers are not able to express, but these are the ones that lend new excitement to an industry.

Figure 7-3 provides a tool with which to understand and develop these two categories of customer needs. At the left end of the spectrum, the product is well aligned with traditional market segments, and customer desires can be more accurately determined with low degree of risk and uncertainty. At the right end of the spectrum, determining customer product requirements requires a much higher degree of uncertainty and risk due to the unknown market segment. "Empathetic Design" refers to understanding user needs through empathy; intangible features such as shape, feel and appearance are often determined in this manner. The tools required for developing these customer requirements for each segment are displayed in the diagram.

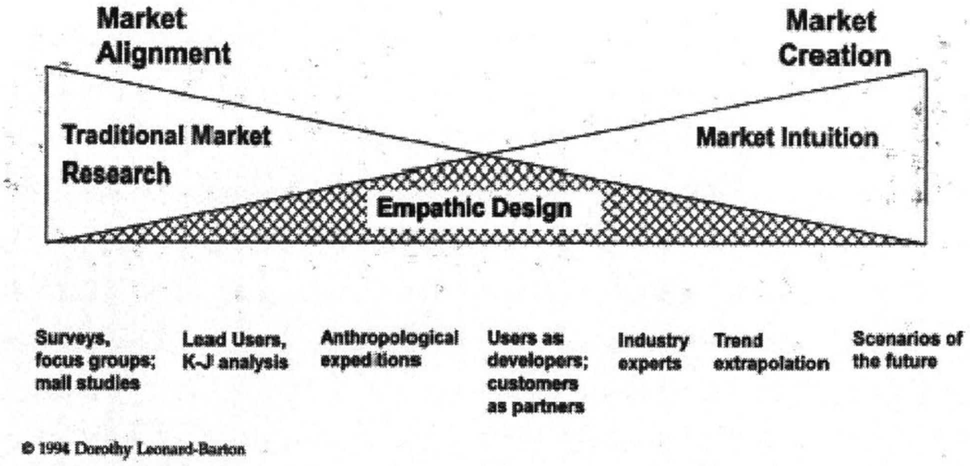

Figure 7-3: Identifying Customer Needs[85]

When surveys, focus groups and mall studies fail to provide appropriate market information, K-J analysis offers an important alternative for evaluating current market needs. The method developed by a Japanese anthropologist, is a highly developed process for gathering and assessing qualitative data. Professor Shoji Shiba has helped to further develop the process and technique in the United States. The process is outlined in the Appendix Figure B. The anthropological expedition refers to developers living in the user environment and empathizing with user needs, analogous to the way in which an anthropologist would inhabit a native village to further their study. And lastly, users as developers are representative of theory that designers should have extensive experience in the 'user world.'[81]

While the Image Engine Case study developed at Kodak centered in understanding the current and future image engine products, there was not ample time to analyze the competitive market and future customer needs in each segment. Platform composite design would require that this research step was not overlooked. The resulting information would prove critical in determining subsystem and component sourcing decisions.

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[80] Meyer, M. and Lehnerd, A., The Power of Product Platforms, New York: The Free Press, 1997.
[81] Rosenbloom, S. and Spencer, W., Engines of Innovation, Boston, MA: Harvard Business School Press, 1996.

7.3.5 Delivery

Once the composite design of the product platform is completed and the assembly has been determined, the next stage is establishing the rollout plan for derivative products. Analysis of the product and technology roadmaps will be critical in this stage in order to plan for timely product delivery. Communication between the Lines of Business and product managers is critical for this stage to be efficiently implemented. Without timely knowledge of future platform changes, the product platform concept will fail to increase margins, lower cost and optimize supplier channels.

The rollout plan for derivative products will only prove successful if improvements for subsystems are identified early enough for the appropriate planning. Timely delivery is heavily reliant on implementing the necessary design changes. It is highly suggested that the team develop a 'power tower' or visual model where the core building blocks or subassemblies, product platforms and derivative products are displayed. In this way individuals may be more likely to take ownership of the platform and contribute their ideas. A model oftentimes takes a theoretical idea and makes it more tangible for the individual.

7.3.6 Team Organization

> *"Integrated Product and Process Development (IPPD): A management technique that simultaneously integrates all essential acquisition activities through the use of multidisciplinary teams to optimize the design, manufacturing, and supportability of processes."*[82]

The last step in the product platform planning and implementation is the organization of an integrated product team. This team should be comprised of members from marketing, product engineering, manufacturing, industrial design & packaging and supply chain. Integrated product teams represent a transition from a functional 'stovepipe focus' to a 'customer product focus.' The graphic included in Appendix Figure C highlights the significant cost savings that result from the utilization of integrated product teams in the product commercialization process.

The only way in which to successfully implement a platform concept is to ensure that all team members take full ownership in the platform. Together the team must work to set clear targets for the functionality of both the current platform and future derivative products. It is absolutely essential that the platform team and key stakeholders agree to all the terms and conditions before the platform implementation phase.

7.4 Success Stories

"Becoming a platform leader is like winning the Holy Grail: Many seek it, but few achieve it."[83]

The successful platform leaders have shaped the direction of technological innovation. In turn, these leaders at their respective firms have directly impacted the work of their suppliers and customers. In their book *Platform Leadership* Gawer and Cusumano[84] stress that successful platform leaders base their product strategy on the principle that core products are dependent on an array of complements. In other words, firm core products are more valuable when the market possesses a large number of complementary products. The authors conclude that the "essence of platform leadership begins with a vision that extends beyond the business operations of one firm or the technical specifications of one product or one component." Platform leaders must channel and guide complementary product innovation to impact not only the current competitive marketplace but also the future landscape.

Gawer and Cusumano provide a set of parameters to guide strategic planning efforts required for successful platform implementation. They are defined as follows: (a) Scope of the Firm, (b) Product Technology, (c) External Relationships, and (d) Internal Relationships.

a) *Scope of the Firm*: To begin, firms must identify which complement to make internally; this is directly related to the exercise of value chain mapping or defining where the firm has the strongest market play. Analysis of the value chain maps and competitive landscape will illustrate where the firm creates value and how best to capture a larger portion of the 'pie.' Firms should only develop complements in areas where they have proven capabilities. The scope of the firm's current capabilities and evolving technologies will aid in helping to define future product platforms. In order to sustain and improve market share platform leaders need to clearly define the interface between the product platform and complementary products.

b) *Product Technology*: The architecture and interface of the product technology must be appropriately defined. Modular architectures can most often reduce the costs of innovation for outside firms. Modules or subassemblies can encourage the emergence of specialized companies to develop innovative complementary products.

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[82] Nightingale, D., Lecture Notes: Lean Engineering Product Development, MIT, September 25, 2002.

[83] Gawer, A. and Cusumano, M., Platform Leadership, Boston, MA: Harvard Business School Press, 2002.

[84] Gawer, A. and Cusumano, M., Platform Leadership, Boston, MA: Harvard Business School Press, 2002.

In order to encourage complementors to enter the market, however, the firm must specify publicly how to interface with the product platform. The firm needs to be extremely careful in this regard in order to protect their intellectual property. While disclosing information pertaining to the product platform interfaces provides a strong method by which to encourage external innovation, disclosing too much information could potentially lower the barrier through facilitation of competitive imitation. Successful product platform leaders therefore must perform a careful balancing of building modular architectures and protecting their core competencies, while at the same time selectively disclosing external interfaces necessary for external complementors to create new innovations.

c) *External Relationships*: Product platform leaders must carefully monitor external relationships. First, these leaders must determine the technical specifications and standards of the product interfaces. This only occurs after consensus is achieved among the key complementors. This process can involve lengthy discussions in order to gain the support from these outside firms. Gawer and Cusumano conclude that platform leaders most often do not move downstream into the complementors' markets in those cases where firms are innovating in areas for which the platform leader is not currently involved. The potential threat of entry by platform leaders, however, does contribute to creating an environment where contributors are not necessarily fully trusting and consensus may take a longer time to achieve.

d) *Internal Organization*: The platform leader must structure the internal organization. The appropriate structure will only be determined once the leader has assessed both the internal and external environments. The platform has a far better likelihood of success if all of the stakeholders enter the implementation phase with the same mindset. The stakeholders must agree on set goals and build firm-wide consensus to ensure a functional internal structure.

Examples illustrative of product platform leaders are provided below. Intel currently serves as the platform benchmark leader, while to a lesser extent NTT DoCoMo and Palm provide strong examples.

7.4.1 Intel

With each new microprocessor generation Intel must make multi-billion dollar investments in product designs and new manufacturing facilities, while there are no absolute guarantees of new customers. Gawer and Cusumano offer Intel as the example of a platform leader because Intel has devoted such significant resources to increasing the market size for all the players.

The Intel Architecture Lab was created in 1991 to address decreasing PC demand, resulting from computer architecture problems. Intel processor chips were becoming ever more powerful; however, the PCI bus (interface) wasn't fast enough to allow customers to gain superior performance. Intel championed efforts to change the PC bus system architecture from PCI to USB.

> *"These interfaces became the technological mechanism for channeling external innovation, ensuring platform integrity through compatibility of complementary products, and creating an industrial consensus on platform technological evolution."*[85]

This is only one example of the many changes that Intel has spearheaded. Intel created business possibilities for many third party companies who adopted the USB interface. These companies, motivated indirectly by Intel to create products that would connect to this new interface had evolved into complementors for the computer platform.

Since its inception in 1991 the Intel Architecture Lab continued to evolve, becoming a catalyst for industry innovation. Researchers worked to generate higher demand for computers (i.e. that in all likelihood would use Intel Processors), through the examination of new computer applications. The Intel Architecture Lab initiatives for 2000 are listed in the Appendix Figure D. This group worked to assess the external relationships (i.e. Gawer and Cusumano's parameter c, as cited above), examining potential market complementors and highlighting business opportunities. In addition, this group created an internal organization (parameter d) that served to foster further development and provide support for this initiative.

7.4.2 Palm

As a company startup, Palm designed a stand-alone device that minimized dependency on external complementors. After much past success, the competitive marketplace has now been transformed and Palm has altered their business strategy to remain competitive. Palm changed its core strategy and decided to separate the operating system from its applications. The firm

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[85] Gawer, A. and Cusumano, M., Platform Leadership, Boston, MA: Harvard Business School Press, 2002.

leveraged their product technology (parameter b) to build a modular architecture around their operating system.

In addition, Palm carefully assessed external relationships (parameter c) to create external complementors that would produce new application innovations. In fact Palm has become increasingly reliant on outside firms to develop their applications. Palm invested significant funding toward facilitating technical training and developing communities of software developers and users. In 2001, studies confirm that there were approximately 145,000 software developers (representing a variety of different companies) who were creating 8,500 applications that were Palm OS compatible.

> *"The term Palm Economy captured the idea that a successful platform creates complementary markets and business opportunities for applications, developers, partners, licensees and OEMs who adopted Palm OS."*[86]

In September of 1999 Palm created an alliance with Nokia, and in October of that same year signed a licensing agreement with Sony. Through both of these contracts, Palm was providing and leveraging their Operating System technology for use in cell phones and other PDA handheld devices.

7.4.3 NTT DoCoMo

NTT DoCoMo has become a leader in Japan by focusing on both their technology platform and their business model. Similar to Palm, the firm has leveraged external relationships (parameter c), encouraging third party firms to create complements for DoCoMo's platform. This firm has formed partnerships with over 800 firms. These complementors have created innovative wireless content accessible through web sites via DoCoMo's handsets known as I-mode. DoCoMo has also helped third parties to simply create unofficial web sites with the strong belief that more interesting content would attract more I-mode users.

The tremendously successful I-mode platform consists of two standards for content creation and data transmission. The first standard, c-HTML is an application programming language targeted at small screen web devices. The second standard, first PDC then PHS, which transitioned W-CDMA defined the mode for data transmission. Managers at DoCoMo transitioned to the CDMA technology to facilitate external development; in addition this multiplexing technique created a barrier to entry for market imitators.

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[86] Gawer, A. and Cusumano, M., Platform Leadership, Boston, MA: Harvard Business School Press, 2002.

These external complementors provide a majority of the content that DoCoMo users can access. While DoCoMo helps to facilitate and encourage the development of these web sites with contract firms, they in turn receive a flat fee for aiding in content creation, and a fixed percentage commission for all user site transactions.

Much of DoCoMo's success can be attributed to their ability to leverage the four platform parameters listed above. First, DoCoMo clearly defined the scope of the firm's capabilities, together with the interface between the product platform and complementary products. Second, DoCoMo appropriately defined their product technology, while maintaining and enhancing their core competencies in data transmission. Third, the firm developed external relationships from which content creators produced new application innovations. And lastly, the firm created an internal organization that aligned all of the stakeholders to enter the platform implementation phase with a shared vision.

7.5 Value Innovation

To maintain market competitive advantage, a firm must ensure innovative and successful product platforms. This requires the firm to perform strategic market analysis in order to develop new product value innovation and monitor disruptive innovation.

> *"In a stable and effective but conservative organizational environment the reward for improving existing technology, products, and processes is greater than the incentive to turn the world on its head. Thus ground breaking changes are viewed as difficult, disruptive, unpredictable, and risky, while incremental innovations are seen as reliably producing more predictable results more quickly."*[87]

Kodak was slow to transition from analog to digital for exactly this reason; that is, the digital marketplace was unpredictable and high risk. In the summer of 2003, Kodak became painstakingly aware that small incremental technological product innovations would lead to further downsizing and profit loss. Consequently the firm has publicly announced the official transition to digital.

Oftentimes when firms examine future innovations they benchmark their competitors to measure industry signs of technological change. After analysis the firm will then attempt to achieve small incremental improvements to surpass their competition. While benchmarking provides an important source for information pertaining to progressive change and continuous improvement, it serves an inadequate source for signals of technological discontinuity.

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[87] Utterback, J., Mastering the Dynamics of Innovation, Boston, MA: Harvard Business School Press, 1994.

Sole use of benchmarking as a strategy has the following consequences on firm achievement[88]:

1. *Imitative Approach*: Firms will imitate current market competitors, attempting to make marginal improvements.
2. *Reactive Strategy*: Firm employees spend the majority of their time fire fighting rather than creating new growth opportunities.
3. *Changing Marketplace*: Firms can potentially lose sight of changing customer demands and emerging mass markets.

Research performed by Kim and Mauborgne illustrated that companies (independent of size, years, industry condition and operation) who pursue value innovation sustain high growth and profits. Rather than focus strategic planning around the competition, the successful firms choose to focus on providing more value to the buyers. While technological innovation is deeply embedded in research and development, value innovation focuses on redefining the strategic initiatives. Examples of corporations who have succeeded as value innovators include (1) Starbucks (coffee), (2) Home Depot (home improvement), (3) Southwest Airlines (short commuter travel), and (4) Wal-Mart (discount retail). These corporations were not the first players to enter their respective markets. Rather, through disruptive innovative value creation these firms provide buyers superior value over their traditional respective industry competitors.[89]

7.5.1 Disruptive Innovation

> *"The power to capture attractive profits will shift in the value chain to those activities where the immediate customer is not yet satisfied with the functionality of available products. It is in these stages that complex, interdependent integration occurs – activities that create steeper economies of scale and greater opportunities for differentiation."*[90]

Disruptive innovation is characterized by a completely new and different way of competing in an existing market segment, one that conflicts with the traditional business practice. Simpler, cheaper and/or more convenient products or services characterize disruptive technologies. Many firms have neglected to forecast disruptive technologies and have consequently failed.

Charitou and Markides examine the tradeoffs faced by established firms in their response to disruptive market innovation. They clearly defined the tradeoffs: (1) Remain focused on the

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[88] Kim, W. and Mauborgne, R. "Strategy, Value Innovation, and the Knowledge Economy," Sloan Management Review, vol. 40, no. 3, 1999, pp.41-55.

[89] Kim, W. and Mauborgne, R. "Strategy, Value Innovation, and the Knowledge Economy," Sloan Management Review, vol. 40, no. 3, 1999.

[90] Christensen, M., Raynor, M., and Verlinden, M., "Skate to Where the Money Will Be," Harvard Business Review, November 2001, pp.71-81.

traditional business regardless of the firm's ability to respond to the market innovation or (2) Incorporate the disruptive innovation into current business strategy through (a) Adopting the disruption and potentially having market play in both segments and/or (b) 'Disrupting the Disruption.'[91]

The disruptive innovation most often targets a different customer segment than that of the traditional business. The disruptive technology offers a new value proposition to this defined market segment and requires a different set of core competencies and capabilities. Senior management may elect not to enter the disruptive market because ramp-up and establishment of the necessary new core competencies presents high risk and/or large capital investments.

On the other hand the firm may elect to incorporate the new disruptive technology into their business strategy. Should the firm adopt this strategy, however, initial examination of the new and traditional market might provide an inadequate illustration of the scope of exploiting interrelationships between two businesses. Rather than focus on the 'cosmetic similarities' firms must assess the suitability of the traditional core competencies for use in the disruptive technology. If the firm's capabilities are in close alignment, then the question of market sustainability and competitor imitation and/or substitution must then be answered before a firm can determine whether to enter the market segment.

In their research, Charitou and Markides found that 68 of the 98 companies which they surveyed opted to embrace the disruptive innovation. Of the 68 companies that elected to adopt the disruptive technology, 62% created a separate business unit. In addition the study found that companies who were effective in competing in both market segments granted a higher level of autonomous decision making to the new business unit. They also opted to share synergies between business units.

In some cases motivation to respond to the disruptive innovation is determined by the degree of risk the firm faces resulting from the disruptive technology or the competitors' market entry. The disruptive innovators eventually become good at targeting and delivering the attributes that traditional customers seek, thereby decreasing the market size of the traditional business. Firms faced with discontinuities involving substitute products are faced with two choices: (1) Adopt the technology or (2) 'Attack back' and disrupt the new innovation.

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[91] Charitou, C. and Markides, C., "Responses to Disruptive Innovation," Sloan Management Review, vol. 38, no. 3, 2003, pp9-24.

The firms who developed the manual typewriter serve as an excellent illustration for the points raised here. When IBM created the electric typewriter the manual typewriter firms failed to successfully adopt the new disruptive technology. As history will record, the typewriter technology gradually transitioned from manual to electric, and then to word processing using the personal computer as we know it today.[92]

Swiss provides an excellent example of firm who chose to 'attack back' and disrupt the new innovation rather than to begin development of imitative disruptive products. Swiss dominated the watch market in the 1960s; the brand was globally recognized for both craftsmanship and the accuracy of their mechanical movements. In the 1970s, Seiko and Timex introduced lower cost quartz technology watches. The Swiss global market share decreased 33% from 1965 to 1980, at which time the firm controlled 15%. While the Swiss brand was recognized for quality of the craftsmanship and accuracy, the disruptive technology focused on new product features and lower price. Rather than create an imitative product to compete directly with Seiko and Timex, in 1983 the firm created the Swatch – the watch emphasizing style was a dashing success, as it quickly became the world's most accepted brand name.[93]

7.6 Summary

This chapter has focused on product platforms as a means to improve image engine performance requirements, reduce costs and increase speed to market. In addition, the chapter has examined the importance of product value innovation and disruptive innovation as a means to ensure efficient and successful strategic planning. As presented in this chapter, Kodak's investment in an image engine platform will prove important in providing a framework in which to achieve an optimized cost structure, robust product families, and successful future growth. Key challenges will be centered in managing the complexity of multiple business units, and obtaining buy-in to the platform from each.

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[92] Utterback, J., Mastering the Dynamics of Innovation, Boston, MA: Harvard Business School Press, 1994.

[93] Charitou, C. and Markides, C., "Responses to Disruptive Innovation," Sloan Management Review, vol. 38, no. 3, 2003, pp9-24.

A major challenge to receiving buy-in is the company culture itself.

> *"It is the history of past success and our human need to have a stable and predictable environment that gives culture such force. Culture is the accumulation of past learning and thus reflects past successes, but some cultural assumptions and behavioral rituals can become so stable that they are difficult to unlearn even when they become dysfunctional."*[94]

The above quote illustrates the powerful impact that culture can play in creating barriers to innovative value creation programs. Analysis of Eastman Kodak will illustrate a deeply entrenched culture that is based on decades of past successes. In most recent times, employees have undergone significant downsizing and unanticipated reorganizations. The ability to implement change programs in this environment may prove extremely challenging. Without the 'psychological safety' or the ability to innovate in safe surroundings, change programs will be constrained. The challenge is therefore to develop innovation sources in a culture where employees feel safe to 'think outside the box.' Corporate-wide programs that aid in shaping and further defining critical strategic goals will serve to encourage high-level innovation.

In creating innovative capabilities internally, a knowledge management system developed with the sole purpose of capturing customer interfaces, internal operations, and upstream supplier interactions is critical to achieve firm competitive advantage. Innovative idea creation and strategic planning will occur through knowledge sharing and the implementation of formal communication networks between the business units.[95]

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[94] Schein, E. "How can Organizations Learn Faster? The Challenge of Entering the Green Room," Sloan Management Review, vol. 34, no. 2, 1993, pp. 85-93.

[95] Quinn, J. "Strategic Outsourcing: Leveraging Knowledge Capabilities," Sloan Management Review, vol. 40, no. 4, 1999, pp. 9-22.

CHAPTER EIGHT: CONCLUSION

8.0 Overview of Findings

The current manufacturing core competencies and respective capabilities were clearly defined. The core competencies were determined as follows: sub-micron alignment of optical and mechanical systems, image system optimization, and image quality test and verification. These core competencies are leveraged across the Lines of Business in a wide variety of products. Chapter 2 describes the manufacturing core competencies and respective capabilities.

The value chain maps configured during this project provide a high-level framework from which to assess Kodak's transition from analog to digital. Traditionally Kodak equipment has been developed and designed to generate output consumables. The value chains created illustrate a lower reliance on consumables. The new value chains highlight the importance of image engines as 'enablers' to optimize digital image quality. Eastman Kodak's operations strategy needs to profitably support and align with this shift in business strategy.

Kodak's strategic dynamic control of image engines would allow the firm to continuously enhance internal learning. This would avoid dependence on other players in the value chain, resulting in increased profits. In addition, strategic dynamic control of image engine core competencies would provide Kodak with a baseline to recognize and value potential growth opportunities. Image engine core competencies must be maintained, enhanced, and further developed in the future. Development funding is required to ensure the continued growth of the internal learning cycle, paramount for maintaining market competitive advantage.

The initial data collected and analyzed clearly suggests that Kodak's investment in an image engine platform will provide a framework from which to achieve an optimized cost structure, robust product families, and successful future growth. Division A has requested a follow-on LFM internship to develop and implement this image engine platform. The platform will provide a centralized clearinghouse for the following activities:

- Knowledge sharing across product line to reduce cycle-time and cost
- Reuse of components and subassemblies across product families
- Investment in new process technologies
- Selection and appropriate management of sourcing partners
- Improved product performance through focused technology leadership

Key challenges will be centered in managing the complexity of multiple business units and obtaining buy-in to the platform from each.

Quality control measures were implemented for the Mini-Fast Scan, the image engine in the Computer Radiography system. The SQL database was created to store critical quality control data measurements. A Gage R&R was created, implemented and analyzed for this subassembly. Analysis of the Gage R&R illustrated high variance in the laser characterization data. An engineering design change was subsequently made for the collimator lens to reduce variance. Control charts demonstrated that the change was indeed successful. An ARIMA time series model was then utilized to assess any time dependencies between batches. In addition, statistical process control was implemented for this assembly process.

8.1 Key Lessons Learned

Kodak has a deeply entrenched culture that is based on decades of past successes. The ability to implement change programs in an environment where employees have undergone significant downsizing and unanticipated reorganizations can prove an extremely challenging task. Corporate-wide programs that aid in shaping and further defining critical strategic goals will serve as a catalyst for high-level innovation and change. Kodak's strategy has been to diversify their product portfolio. As a result knowledge sharing and communication networks required to assess potential synergies between units have not been optimized. This corporate strategy group can work to create a shared corporate vision and encourage communication between the Lines of Business. Through a comprehensive focus on organizational structure, future market segments, and transformational change, this strategic corporate strategy group will provide a solid framework to ensure appropriate core competency planning and future firm growth.

APPENDIX

Figure A: ARIMA Non-Seasonal Models[96]

(1) If the series has positive autocorrelations out to a high number of lags, then it probably needs a higher order of differencing.

(2) If the lag1 autocorrelation is zero or negative, or the autocorrelations are all small and patternless, then the series do not need a higher order of differencing. If the lag1 autocorrelation is -.5 or less, the series maybe over-differenced.

(3) The optimal order of differencing is often the order of differencing at which the standard deviation is lowest.

(4) A model with no orders of differencing assumes that the original series is stationary (mean-reverting). A model with one order of differencing assumes that the original series has a constant average trend (e.g. a random walk or SES-type model, with or without growth). A model with two orders of total differencing assumes that the original series has a time-varying trend (e.g. a random trend or LES-type model).

(5) A model with no orders of differencing normally includes a constant term (which represents the mean of the series.) A model with two orders of total differencing normally does not include a constant term. In a model with one order of total differencing, a constant term should be included if the series has a non-zero average trend.

(6) If the PACF of the differenced series displays a sharp cutoff and/or the lag1 autocorrelation is positive, for example if the series appears slightly "under differenced" then consider adding an AR term to the model. The lag at which the PACF cuts off is the indicated number of AR terms.

(7) If the ACF of the differenced series displays a sharp cutoff and/or the lag1 autocorrelation is negative, for example the series is slightly over differenced, then consider adding an MA term to the model. The lag at which the ACF cuts off is the indicated number of MA terms.

Figure: Adapted from Duke University Decision 411 Forecasting Lectures

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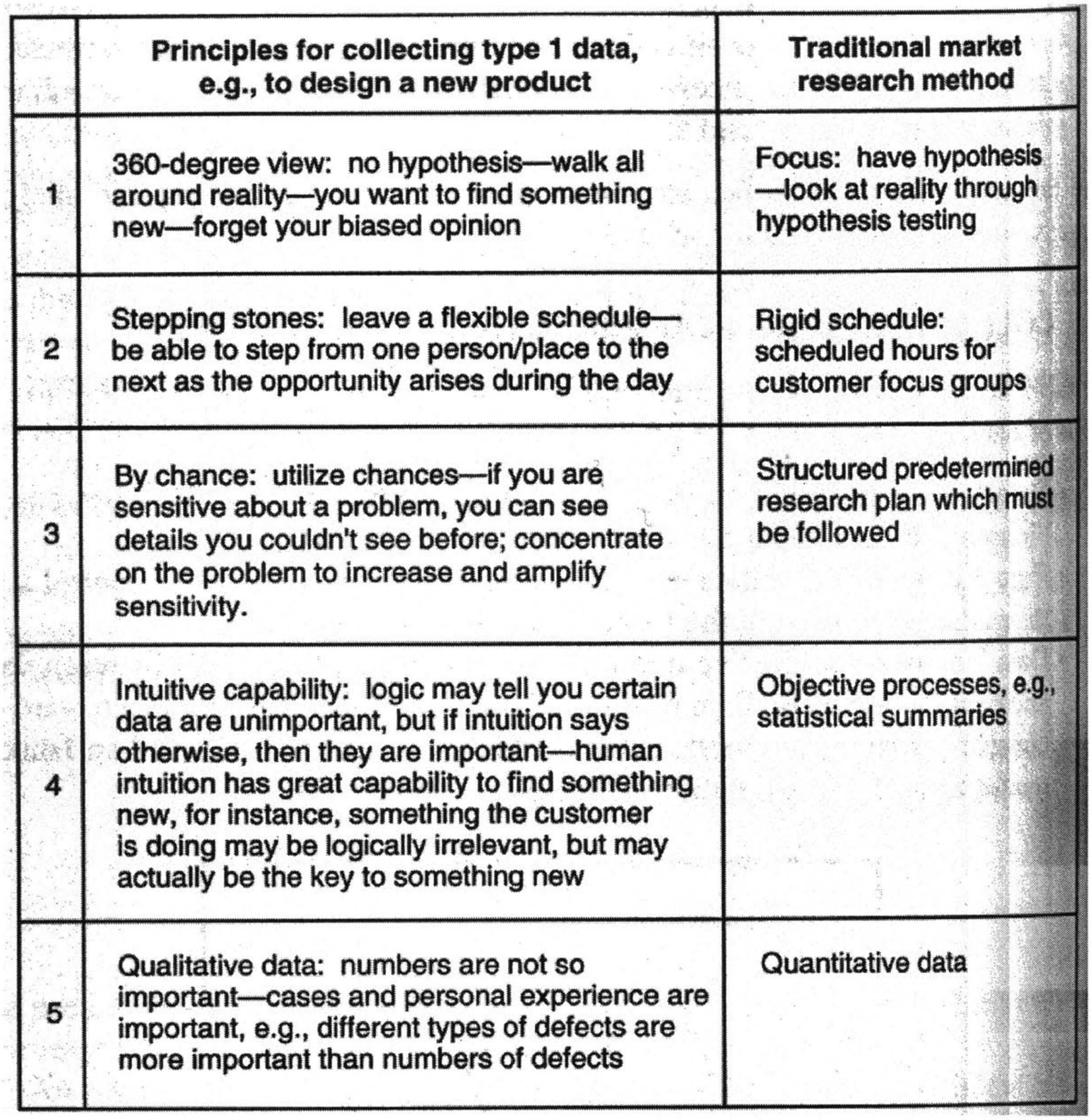
[96] Decision 411 Forecasting Lecture Notes, Duke University, 2003, <http://www.duke.edu/~rnau/411>.

Figure B: KJ Analysis



	Principles for collecting type 1 data, e.g., to design a new product	Traditional market research method
1	360-degree view: no hypothesis—walk all around reality—you want to find something new—forget your biased opinion	Focus: have hypothesis —look at reality through hypothesis testing
2	Stepping stones: leave a flexible schedule—be able to step from one person/place to the next as the opportunity arises during the day	Rigid schedule: scheduled hours for customer focus groups
3	By chance: utilize chances—if you are sensitive about a problem, you can see details you couldn't see before; concentrate on the problem to increase and amplify sensitivity.	Structured predetermined research plan which must be followed
4	Intuitive capability: logic may tell you certain data are unimportant, but if intuition says otherwise, then they are important—human intuition has great capability to find something new, for instance, something the customer is doing may be logically irrelevant, but may actually be the key to something new	Objective processes, e.g., statistical summaries
5	Qualitative data: numbers are not so important—cases and personal experience are important, e.g., different types of defects are more important than numbers of defects	Quantitative data

Figure: Comparison of Kawakita's 5 Principles with Traditional Market Research Methods[97]

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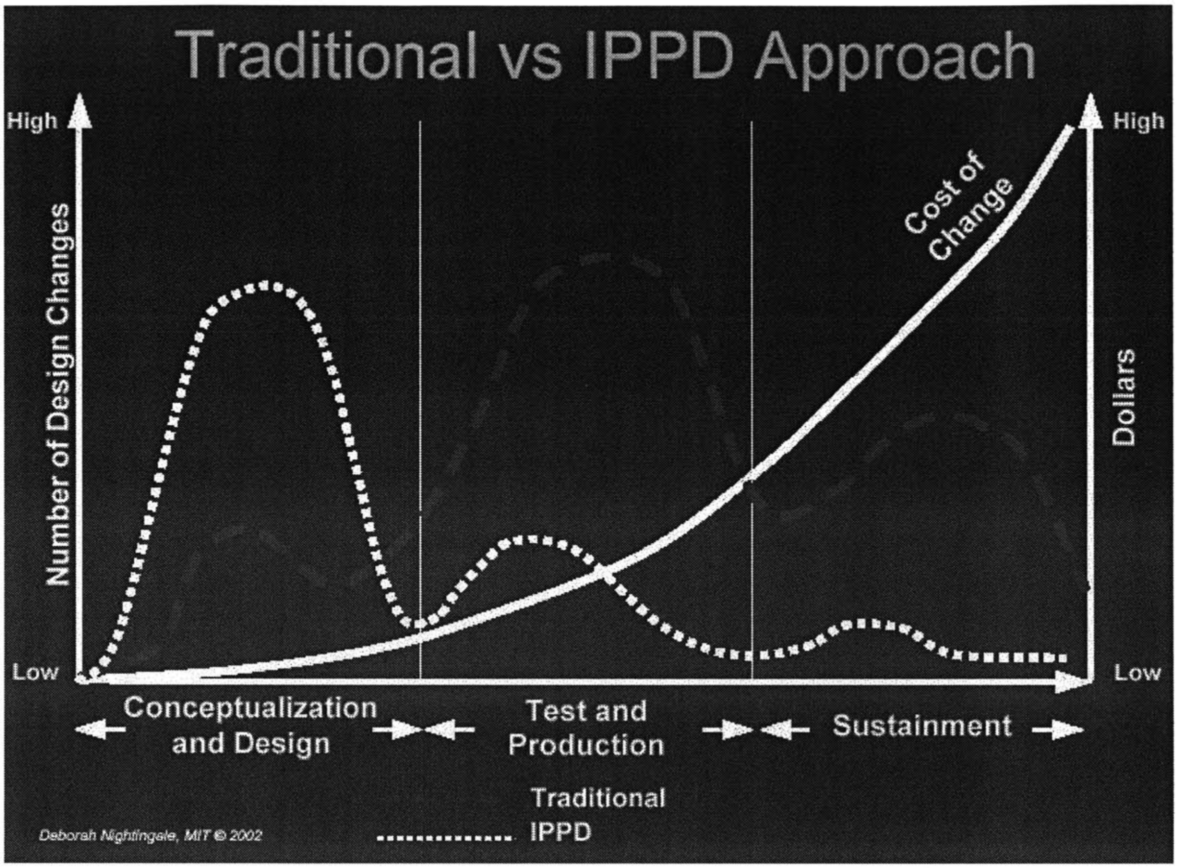
[97] Shiba, S. and Walden, D., Four Practical Revolutions in Management, Cambridge, MA: Center for Quality Management, 2001.

Figure C: Power of an Integrated Product and Process Development Team[98]



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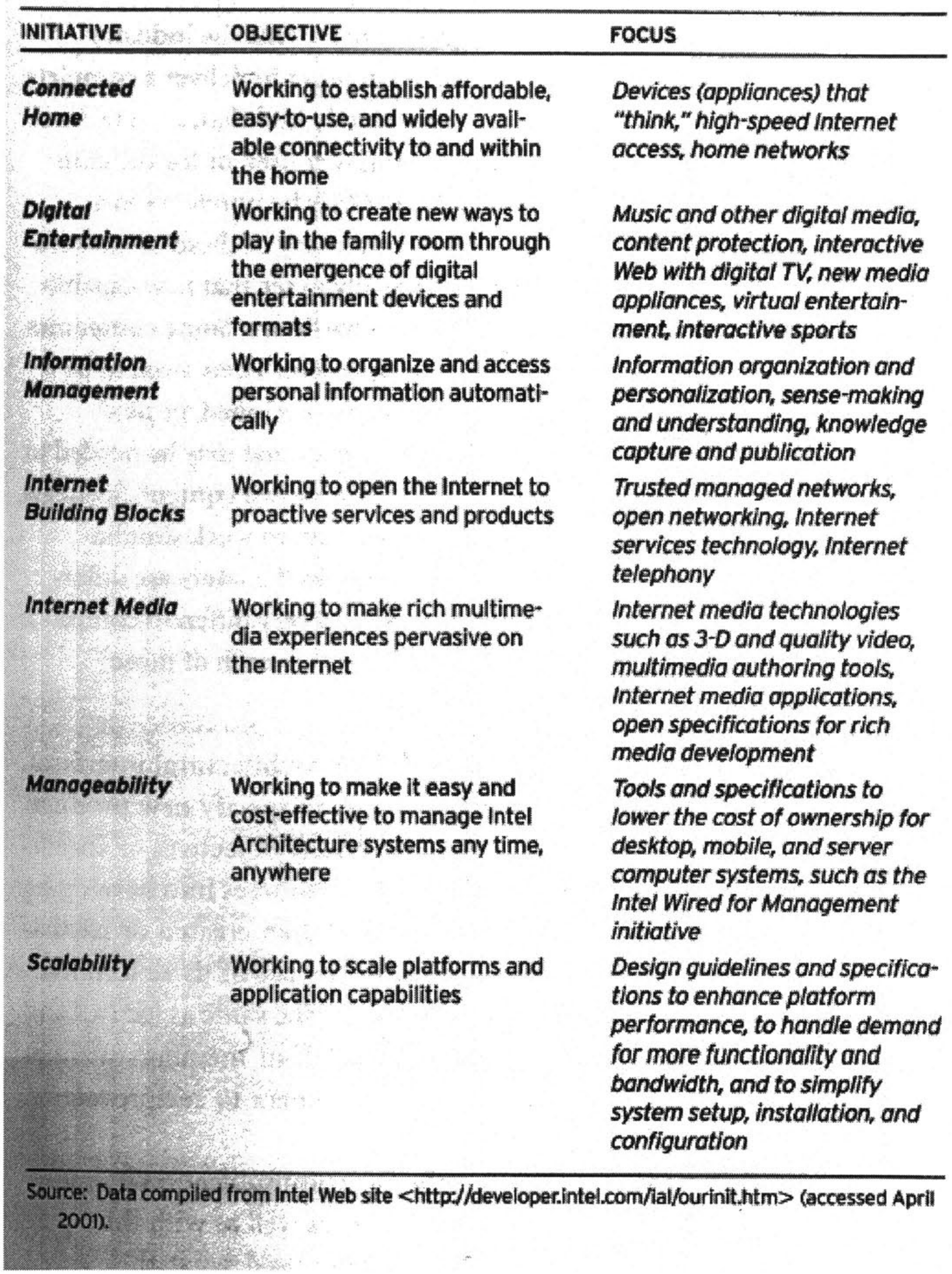
[98] Nightingale, D., Lecture Notes: Lean Engineering Product Development, MIT, September 25, 2002.

Figure D: IAL Seven Initiatives for 2000[99]



INITIATIVE	OBJECTIVE	FOCUS
Connected Home	Working to establish affordable, easy-to-use, and widely available connectivity to and within the home	*Devices (appliances) that "think," high-speed Internet access, home networks*
Digital Entertainment	Working to create new ways to play in the family room through the emergence of digital entertainment devices and formats	*Music and other digital media, content protection, interactive Web with digital TV, new media appliances, virtual entertainment, interactive sports*
Information Management	Working to organize and access personal information automatically	*Information organization and personalization, sense-making and understanding, knowledge capture and publication*
Internet Building Blocks	Working to open the Internet to proactive services and products	*Trusted managed networks, open networking, Internet services technology, Internet telephony*
Internet Media	Working to make rich multimedia experiences pervasive on the Internet	*Internet media technologies such as 3-D and quality video, multimedia authoring tools, Internet media applications, open specifications for rich media development*
Manageability	Working to make it easy and cost-effective to manage Intel Architecture systems any time, anywhere	*Tools and specifications to lower the cost of ownership for desktop, mobile, and server computer systems, such as the Intel Wired for Management initiative*
Scalability	Working to scale platforms and application capabilities	*Design guidelines and specifications to enhance platform performance, to handle demand for more functionality and bandwidth, and to simplify system setup, installation, and configuration*

Source: Data compiled from Intel Web site <http://developer.intel.com/ial/ourinit.htm> (accessed April 2001).

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[99] Gawer, A. and Cusumano, M., Platform Leadership, Boston, MA: Harvard Business School Press, 2002.

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