

DEVELOPING ORGANIZATIONAL LEARNING
CAPABILITIES FOR IMPROVED MANAGEMENT
OF TECHNICAL KNOWLEDGE

by

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ABSTRACT

The transition from job-shop to standardized manufacturing can be very difficult to manage. These manufacturing systems require two very different sets of process designs, process technologies, operational procedures, organizational structures, and organizational capabilities. All of these factors must be considered when formulating a strategy to make this transition. Process development capability is the key component of a business strategy that encompasses all of the above factors and enables a company to make the transition smoothly.

One managerial approach to process development that supports production planning is to design an idealized manufacturing system. Comparing the idealized design to current technologies available to the company focuses process development on developing the needed technologies. When the current technical knowledge is inadequate for developing the needed technologies and resources are constrained, organizational learning processes and managerial leadership are required. A company's capability for rapid development and implementation of technical knowledge can be a competitive advantage.

This research focuses on the organizational culture, the management of technical knowledge, and the organizational learning capabilities that rapidly develop technical knowledge and lead to efficient manufacturing processes. Through teamwork with Polaroid's Holographic Products Division (HPD), I was able to diagnose HPD's methods for managing technical knowledge and identify organizational obstacles to improved process development capabilities. By performing a cultural analysis with a product development team, I tailored a strategy for developing organizational learning capabilities for HPD's needs. By enhancing a few learning orientations and facilitating factors for the organization, process development capability can be improved and the business strategy to transition from job-shop to standardized manufacturing can be made more effectively.

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1. Thesis Statement

A company that has been successful because of a visionary founder, who individually advanced technology and provided strong leadership to forge new patent-protected markets, may have difficulty succeeding once the founder moves on. Inspired by the founder's genius and reposed with a comfortable market position, the company can become complacent in its manufacturing and process development activities. These are the activities that promote the capabilities needed for successful integration of complex technologies and commercialization of product innovations.

Today's markets are becoming more competitive and an expanse of new and varied technologies must be integrated to create increasingly complex products. This higher level of competitiveness and technical complexity requires a company to have more than just one great visionary to drive product and process innovation – it requires the more effective use of organizational learning. By harnessing the creativity of the many minds in an organization, the integration of complex technology can lead to many more products that meet many more of the customer's requirements.

1.1 Background

This thesis research is being completed as part of a Leaders for Manufacturing internship with the Polaroid Corporation. Polaroid manufactures instant photographic cameras and films, digital imaging products, medical diagnostic imaging media, graphics imaging systems, polarizers, sunglasses, and holographic films for markets worldwide. This research was completed within the context of the Holographic Products Division (HPD) at Polaroid. The outcomes are expected to benefit the company through improved operations, while the internship provided me the opportunity to apply chemical engineering and management science concepts in an industrial setting.

This research focuses on organizational culture, management of technical process knowledge, and organizational learning capabilities that lead to advanced products and efficient

manufacturing processes for technically complex markets. These issues are important for the general business community because recent downsizing across corporate America make learning capabilities essential for companies that operate with fewer resources in a world of increasing product complexity and market competitiveness.

1.2 Problem Description

HPD's current holography manufacturing system is well suited for flexible, job-shop style manufacturing of many product lines in small quantities; this type of system is appropriate for Polaroid's branded and custom-made consumer product families. HPD has been given a new business focus: to pursue profitability. An avenue to profitability has been identified in its industrial business line; it is developing holographic diffusers for display brightness enhancement when used with liquid crystal displays (LCDs). Recent sales growth in the industrial business line has outpaced all other product sales. The industrial products have more standard quality specifications, and industrial customers demand higher volumes. A new manufacturing system is now needed that can produce holographic diffusers in large volumes with greater consistency, efficiency, and uniformity in quality.

The transition from job-shop to standardized manufacturing can be very difficult to manage. These manufacturing systems require two very different sets of process designs and technologies, operational procedures, organizational structures, and organizational capabilities in order to perform competitively. One managerial approach is to develop an ideal design of a manufacturing system for producing holographic diffusers, identify what technologies are currently available to the company that can be integrated into the ideal design, and develop other technologies needed to approach the ideal design. HPD's current technical process knowledge for designing an ideal manufacturing system is inadequate. The appropriate organizational learning processes and managerial leadership are needed for rapid development of the technical knowledge that will advance the current manufacturing system to the ideal system design for high quality/quantity production.

1.3 Thesis Structure

The three issues outlined above – organizational culture, management of technical process knowledge, and organizational learning capabilities – are explored and explained throughout this thesis. During my internship at Polaroid, I participated on three teams. Through my experience with these teams and a formal cultural analysis session, I discovered a lot about organizational culture – especially the cultures of Polaroid and HPD. On each of these teams I was involved in eliciting the process issues that needed development. In pushing the process development activities forward, I learned about Polaroid’s methods for managing technical process knowledge. These methods varied greatly from those that I experienced as a process development engineer in the pharmaceutical and biotechnology industries. The contrast in methods for managing technical process knowledge led me to believe that HPD needed to develop organizational learning capabilities to enhance its process development activities.

In order to provide some background information and the context of the internship, I have written Chapter 2 as a case study. This is a situational case study of HPD’s reorganization and change in business focus. The case study is meant to initiate your thoughts on business and manufacturing strategy, and to outline the implementation issues involved with a change in strategy.

Chapter 3 reviews my experiences with three teams and the process development and engineering issues that I encountered. Russell Ackoff’s systemic approach to process development of an idealized design¹ is presented and tested with one of the teams. Chapter 4 explores the literature on corporate strategy, and the importance of process development and technical process knowledge management to strategy implementation. This chapter also provides the direction for research within an analytic framework for managing technical process knowledge.

Chapter 5 summarizes a cultural analysis of HPD. The cultural analysis surfaces some of the deep underlying assumptions of the HPD culture that suggest an approach to developing organizational learning capabilities. Considering the outcome of the cultural analysis, Chapter

¹ R.L. Ackoff, LFM ProSeminar Video, 1989.

6 presents the concepts of a learning organization and outlines an implementation strategy for HPD to pursue in developing its own organizational learning capabilities. My conclusions and recommendations for future research are presented in Chapter 7.

2. A Case Study of the Holographic Products Division (HPD)

This chapter is written as a case study to illustrate the context within which my internship occurred. It was a very dynamic setting, experiencing a reorganization and refocusing of the business strategy. At the time I arrived at Polaroid, holography manufacturing was experiencing quality problems with its new product Imagix® – a holographic diffuser. My supervisor had just started with HPD as the product development manager. Because of the manufacturing quality problems, his responsibilities also included improving the quality and reliability of the tools made for holography manufacturing. The employees within the manufacturing organization insisted they could meet the quality requirements for the new Imagix® products as long as the tools were made to specification. Unfortunately, the tool specifications for the manufacturing of the new products were unclear.

HPD designs and manufactures holographic images, serving a display business line (including consumer, promotional, and security products) and an industrial business line (holographic optical devices). The manufacturing infrastructure is well established to support the display business, which consists largely of custom-imaged products. HPD intended to use the profits from the display business to support extension of its optical device applications, but only one year in the last 13 was profitable.

Major business opportunities are believed to exist in holographic optical devices, where the added value is high and where HPD's photopolymer system provided the greatest impact for differentiation. A newly appointed vice president had been recruited to improve HPD's profitability. He had committed HPD to pursue the industrial business opportunities with greater focus and instituted a reorganization through layoffs to reflect this change in business focus and to provide short-term profitability.

With this abrupt change in production focus, manufacturing started to experience major quality problems. Holographic optical devices have more standard quality specifications and are sold in larger volumes. Industrial customers expected greater product quality and

durability than traditional display customers. It didn't help that HPD had made promises to customers concerning delivery and quality that would be very difficult to meet. My supervisor believed in this new business focus and felt it was a key step toward developing the capabilities needed to support the new product development projects he was managing. Still, he wondered: Did manufacturing have the right capabilities for high quality/high volume production? What new process technologies would be needed and how could they be developed under this new reality? How would this shift in product focus affect the manufacturing organization and the product development programs? What could he do to make this transition smoothly?

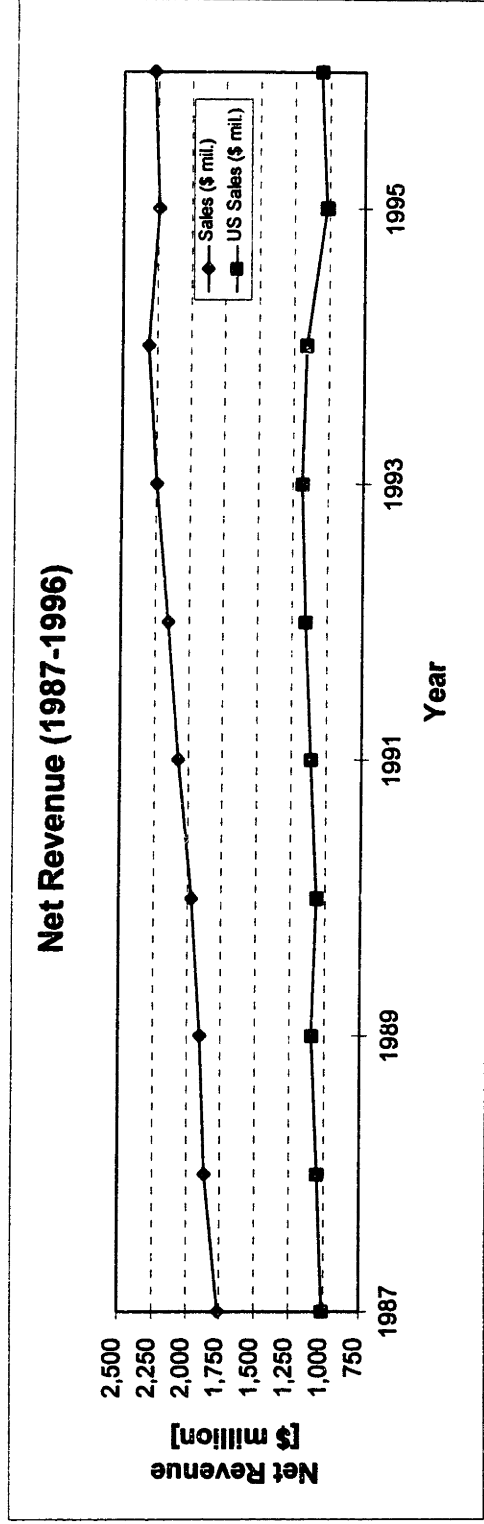
2.1 Company Background

Polaroid Corporation, with 1995 sales of more than \$2.2 billion, is the worldwide leader in instant imaging. Polaroid supplies instant photographic cameras and films, electronic imaging products, medical diagnostic imaging systems, graphics imaging systems, polarizers, and holographic films to markets worldwide. Instant photography, driven by U.S. sales in the past, has always been the cash cow of the company. Lately, the company has needed to change its traditional markets to spark sales growth [see Figure 2.1]. In 1995, a new chief executive officer was appointed with the goal of igniting growth in Polaroid's stagnant product sales and product development. An early focus on emerging markets has provided some growth, but more dramatic change is still required.

Some major business areas that Polaroid is attempting to grow in are digital, medical, and graphics (high resolution printing) imaging. Polaroid is made up of a number of divisions, all of which are microcosms of the Polaroid culture with some minor differences specific to each division's history and experiences. A strong culture was inculcated through the long and dominant leadership of founder Edwin Land.

Figure 2.1: Polaroid's Financial Performance

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Sales (\$ mil.)	1,764	1,863	1,905	1,972	2,071	2,152	2,245	2,313	2,237	2,275
Net income (\$ mil.)	116	(23)	145	151	684	99	68	117	(140)	15
Income as % of sales	6.6%	--	7.6%	7.7%	23.2%	4.6%	3.0%	5.1%	--	0.7%
Earnings per share (\$)	2	(0)	2	2	11	2	1	2	(3)	0
Stock price - high (\$)	43	44	50	48	29	35	39	37	49	49
Stock price - low (\$)	17	22	35	20	20	24	26	29	29	39
Stock price - close (\$)	24	37	46	23	27	31	34	33	47	44
P/E - high	23	--	26	22	3	17	27	15	--	152
P/E - low	9	--	18	9	2	12	18	12	--	122
Dividends per share (\$)	1	1	1	1	1	1	1	1	1	1
Book value per share (\$)	17	14	3	4	15	17	16	19	16	14
Employees	13,662	11,613	11,441	11,768	12,003	12,359	12,048	12,104	11,662	10,046
US Sales (\$ mil.)	1,010	1,050	1,090	1,060	1,110	1,150	1,180	1,160	1,020	1,060



2.1.1 Technology Driven Culture

As a Harvard University undergraduate in the late 1920s, Edwin Land began the research that led him to develop the world's first synthetic light-polarizing material, which he named Polaroid. By 1927, he identified the use of polarization to control the glare from automobile headlamps. In 1932, Land had dropped out of Harvard to start Land-Wheelwright Laboratories. Initial research areas were in fuel cells, headlight systems, camera filters, and sunglasses made of "Polaroid" glass. In 1936, Land introduced a three-dimensional movie projector that used Polaroid lenses to create stereoscopic effects. All of these research projects were cutting edge technology, but failed to be commercialized on a large scale.²

During the 1930s, the company licensed the use of its polarizing material, using the resulting cash to fund further research and development. By 1940, Polaroid had developed a strong scientific faculty and began bidding on Navy contracts. With the escalation of World War II, Polaroid became more entrenched as a research company with military research and development as its primary activity. This research was focused in the areas of optical ring sights, rangefinders, guidance systems, and infrared sensors. By 1943, Polaroid had assimilated a wealth of technology and experience in the physics and chemistry of photography that permanently changed the course of the company. Its sales rose from \$1 million in 1941 to over \$15 million by 1945. Sales dropped back to about \$1.5 million in 1947.

During a vacation in New Mexico, Land's three-year-old daughter innocently asked why she could not see the pictures they had taken earlier in the day. Land's answer to her question was the beginning of the new instant photography industry. After the war, Land refocused the company on the SX-70 camera project to commercialize instant photography. Because Polaroid's capabilities were research oriented, Land decided that outside suppliers would be used for initial manufacturing. Later, in the 1970s, Polaroid pursued a strategy of backward integration and manufacturing development; this strategy moved the company out of the

² Polaroid history taken from P.C. Wensberg, Land's Polaroid: A Company and the Man Who Invented It (Houghton Mifflin Company, Boston, MA, 1987).

monopolistic grip of its supplier, Kodak, and enabled Polaroid to better protect its instant photography business.

Land held over 530 patents, second only to Thomas Edison. He was considered to be a genius who took nothing for granted, accepted no common knowledge, tested the cliché, and treated conventional wisdom as an oxymoron. As a result of Land's continual push on technology, Polaroid was continually introducing new products and product improvements.³

While the firm was in the organic form, Land maintained a flexible organizational structure with an informal information flow and centralized decision making. This organizational structure worked well because the decision power resided with the founder – the one person most capable of making decisions. Land was the only person with complete knowledge of the initial photography projects. The reasoning was based on concerns for secrecy in the photography business. Land and upper management were responsible for ensuring product innovation. The system of centralized decision making focused on product innovation and left process innovation as the responsibility of all other employees. While Land was in charge, science and technology drove Polaroid's product introductions and commercial success. By pushing the edge of chemistry and physics technology, Land created products that left consumers wonder-struck.

Polaroid has expanded its business in the imaging industry, which includes photocopying, printing, and video as well as photography. Helios, its system for recording diagnostic images with no chemical processing or toxic fluids, was released in 1993, two years behind schedule. Polaroid introduced three new technologies in 1995 – a new lithographic printing plate, a direct digital color proofer, and direct digital plates. Late that year, former Black & Decker executive Gary DiCamillo was named chief executive officer of Polaroid and soon announced plans to cut the company's workforce by 20 percent. Restructuring charges led to a \$140 million loss for the year [see Figure 2.1].

³ Ibid.

2.1.2 History of the Holographic Products Division

The Holographic Products Division (HPD) was established in 1984 as a technology outgrowth of Polaroid's research laboratories. The division was set up as an integrated business unit with fully dedicated application development, marketing and sales, and manufacturing resources. Its business covered two sectors: display and industrial. The display product lines were three-dimensional images designed for visual impact in consumer products and for original equipment manufacturer's (OEM) promotional, product, and authentication needs. The industrial product lines were optical devices designed for OEM light management and information presentation needs.

HPD's mission is "to use holography to manage light for visual impact." Polaroid expected HPD to provide incremental top and bottom line growth, to help make Polaroid attractive to a new global generation, and to build an entrepreneurial model for Polaroid's people. Since 1984, the division has lost between \$2-10 million per year except for 1991 when the Gulf War resulted in many government contracts and a slim profit for that year. For the past few years, HPD's losses have been trending lower [see Figure 2.2]. Today, HPD designs and manufactures holographic images for consumer products, promotional materials, and security applications, and some holographic optical devices for industry.

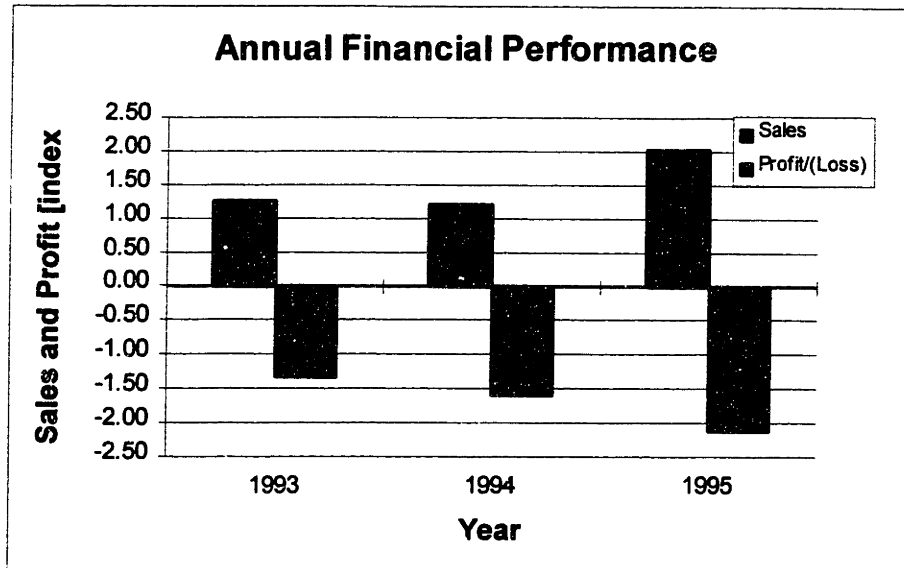


Figure 2.2: HPD's Financial Performance

2.2 “Holography 101”

Dennis Gabor, an electrical engineer, won the 1971 Nobel Prize in physics for his work during World War II that laid the groundwork for holography. Holography is a method for making three-dimensional images. A hologram is a piece of film or glass coated with a photographic emulsion or polymer that has been exposed to laser light reflected by a three-dimensional object. Holographic images record and playback the amount, the wavelength, and the angles of incidence of light striking the recording medium. When you shine a light on the hologram, a three-dimensional image appears to float behind or in front of the surface.

There are two fundamental types of holograms: surface relief, or embossed, and volume-phase. Embossed holograms record information at the surface of the medium; they are very inexpensive to produce, but have limited optical capability. Volume-phase holograms record information throughout the depth of the film; the optical capabilities are very versatile, but they are difficult to mass produce. HPD is the world’s largest volume-phase hologram manufacturer.

Volume-phase holograms can be made in two different modes: transmission and reflection. Transmission holograms require the light to shine through the back of the holographic film. Reflection holograms require light to shine on the front of, and to reflect back through, the holographic film. Some holograms can only be seen when lit with laser light; other holograms, called rainbow holograms, can be seen when lit with white light. HPD's reflection holograms are lit with white light, filtering out all but one color, which is used to form the image. In order to record a three-dimensional light interference pattern, the light used must be highly directional and of one color; this type of coherent light is emitted by a laser.

Initially, holograms were used to record and play back three-dimensional images without special viewing devices. Recently holographic technology has been used for creating complex optical devices that direct light in precisely controlled ways. Applications have included mirrors, lenses, diffusers, and couplers [see Figure 2.3 and Figure 2.4] that operate at specific wavelengths and directions, at even microscopic scale.

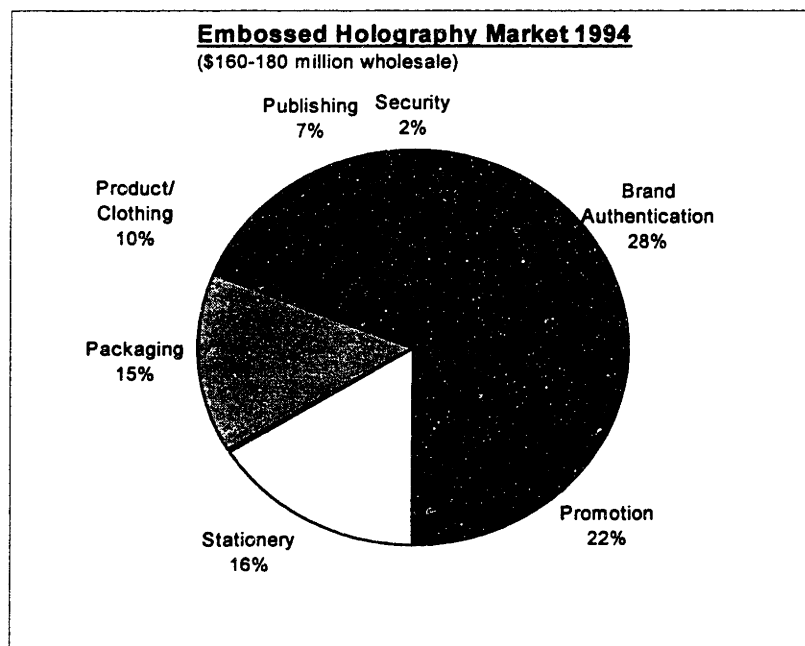


Figure 2.3: Embossed Holography Market

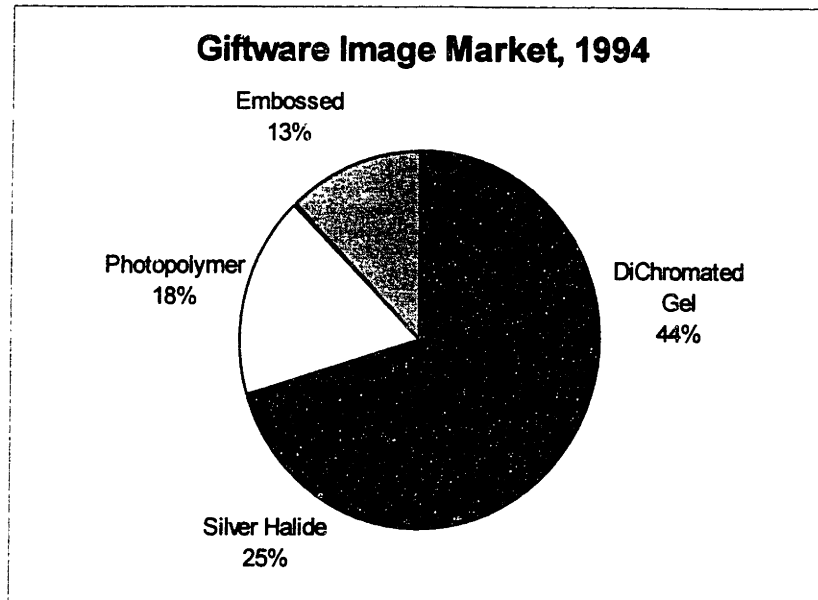


Figure 2.4: Market Share for Different Holographic Materials

2.3 Holography Manufacturing

HPD has a patented photopolymer system for recording volume-phase holograms. The prepolymer mix can be readily coated on flexible base supports typically used in photographic film. The patented photopolymer system produces very stable holograms with the best optical capability in the industry.

The manufacturing process starts with the coating of a pre-polymer film onto a flexible base in a light-, temperature-, and humidity-controlled environment. The coated sheet is then passed through a conditioning chamber before being imaged. After exposure, the sheet is treated with light in a controlled environment and with chemicals to “freeze” the hologram and increase the image durability. At this stage, the “bulk” holograms are stored until needed for conversion to customer configurations. At various stages within this process there are slitting operations and inventory buffers. The slitting operation cuts rolls to a specified width [see Figure 2.5].

Conversion of rolls to customer product configurations starts with lamination of both sides of the sheet with different laminates, depending on the product. After lamination, the

holograms are die cut into individual pieces for final finishing and assembly. Each individual hologram is inspected by quality control before shipping to the customer or assembler.

By 1995, HPD had developed the manufacturing infrastructure needed to support the display business. Drawing from supporting core competencies of Polaroid, manufacturing developed a unique and proprietary facility for large volume production of custom-designed holograms at affordable market prices. A network of external vendors is in place to convert holograms to user's product format. The display business line was supposed to be the profit engine in the immediate term, provide near-term growth, and support the development of holographic optical device applications.

Other than the consumer markets, the display holograms are sold also in the business-to-business marketplace, where the use of holograms provides measurable added value in product enhancement, product authentication/security, and increased promotional visibility. Target markets included labeling and packaging, ticketing (for sporting and other entertainment events), greeting cards, advertising, toys, and novelty items

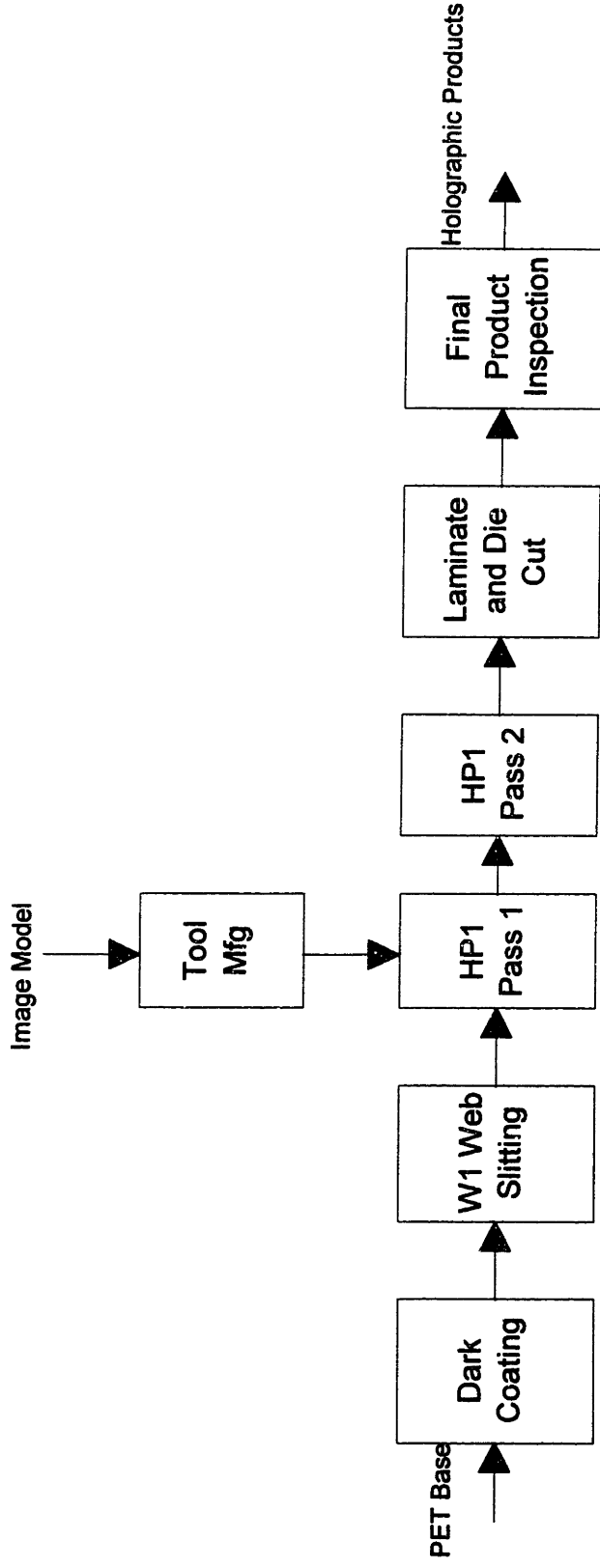


Figure 2.5: Holography Manufacturing Process Flow

2.4 Current Situation

Display products contributed an average margin of 30 percent (with a range of 10-40 percent). Display customers ordering custom images were not as reliable as OEMs in submitting purchase orders and paying for product received. Often the display salesman would accept sales and manufacturing would start making the order without a purchase order in hand. The result was a lot of hard-to-sell, specialized inventory and uncollectable accounts receivable.

In the past few years, the number of display products proliferated. Total sales growth was relatively slow, with a jump in consumer product sales when HPD introduced its own branded product [see Figure 2.6]. Although the average order size had been growing for the last few years, regular display product orders were small and created a “job shop” style of operation [see Figure 2.7].

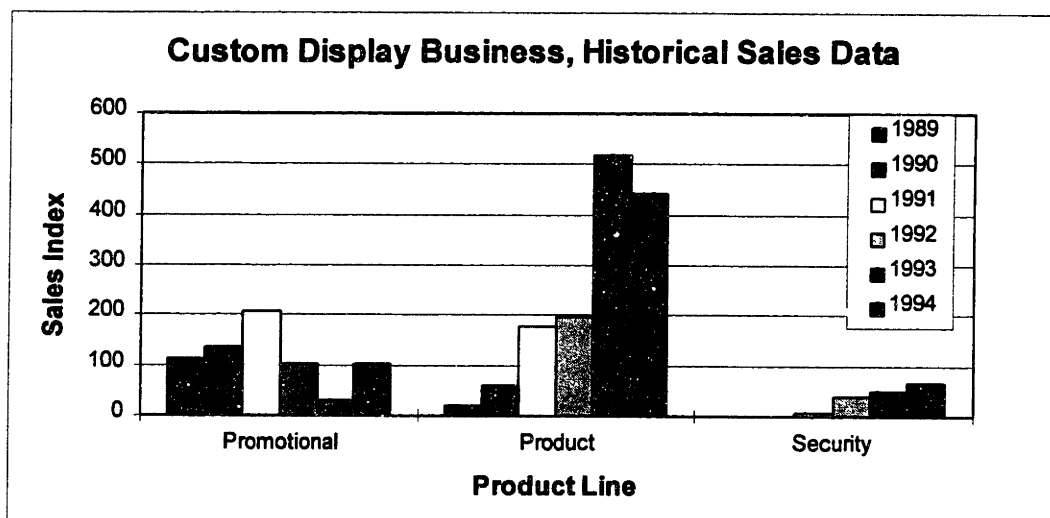


Figure 2.6: HPD Sales

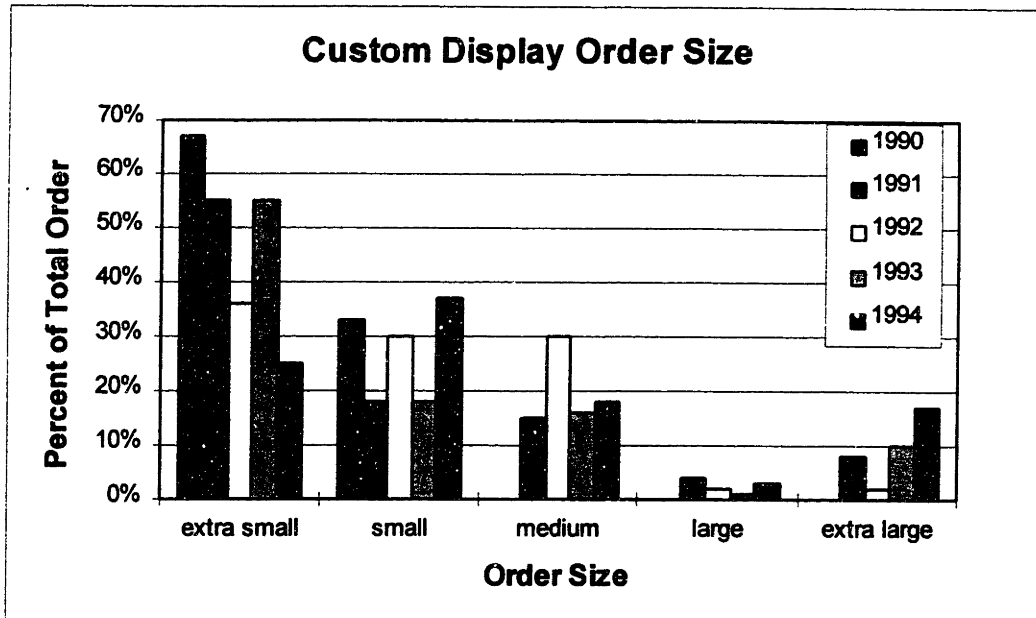


Figure 2.7: Display Product Orders

Toward the end of 1995, HPD was approached by an industrial company, with businesses in the high-tech and communications industries, to establish a partnership for developing a new industrial application of holographic technology. The idea was to make holographic diffusers that provide a brightness background for liquid crystal displays (LCDs). Using a brightness enhancer gives the appearance of a backlit display, reduces the power consumption for backlit displays, and provides differentiation for OEM customers. HPD named the product Imagix®.

Initial market tests of Imagix® showed great market promise. At the 1995 TELECOM conference in Geneva, one attendee commented, "This pager looks awesome - especially the display!"⁴ By adding Imagix® to LCD products, OEMs could capture a 40-60 percent premium on sales. At the 1995 conference of the Society for Information Display, the

⁴ internal Polaroid document

keynote speaker commented that, “There have been three paradigm changes in LCD technology in the past 15 years. This is one of them.”⁵

HPD would use this partnering opportunity to co-develop the brightness enhancer product and manufacturing technology and would negotiate to retain marketing rights for third-party OEMs and LCD manufacturers not competing with the partner. The marketing strategy involved selling to OEMs, establishing distribution channels, and developing relationships with external experts to meet special business needs (i.e., licensing, lead generation, and promotional activities).

The Imagix® product development strategy was to establish product specifications through the partnership and then to sell standardized products to as many other markets as possible. Because of the nature of the photopolymer and the manufacturing process, the original products would have to be colored holograms. Colored holograms could only be used with black and white LCD, which was only 25 percent of the \$6.8 billion market in 1995. HPD estimated it could capture 25 percent of this market, or roughly \$400 million by 1998 [see Figure 2.8 and Figure 2.9]. These estimates assumed that business with the partner would only be 5 percent of its total sales and that there would be many third-party and low-end customers. Development of an achromatic product would be pursued to capture the color LCD market with the potential to increase sales five-fold.

The manufacturing strategy was to use the partnership to drive quality standards and manufacturing capability with the integration of industrial products into the manufacturing stream. Internal manufacturing would concentrate on hologram production while conversion to customer-ready products would be outsourced.

HPD had similar display enhancement product in development with applications for other markets estimated to be three times as large as the LCD markets. To complete this development without a partner required an estimated \$15 million and 4-5 years.

⁵ Ibid.

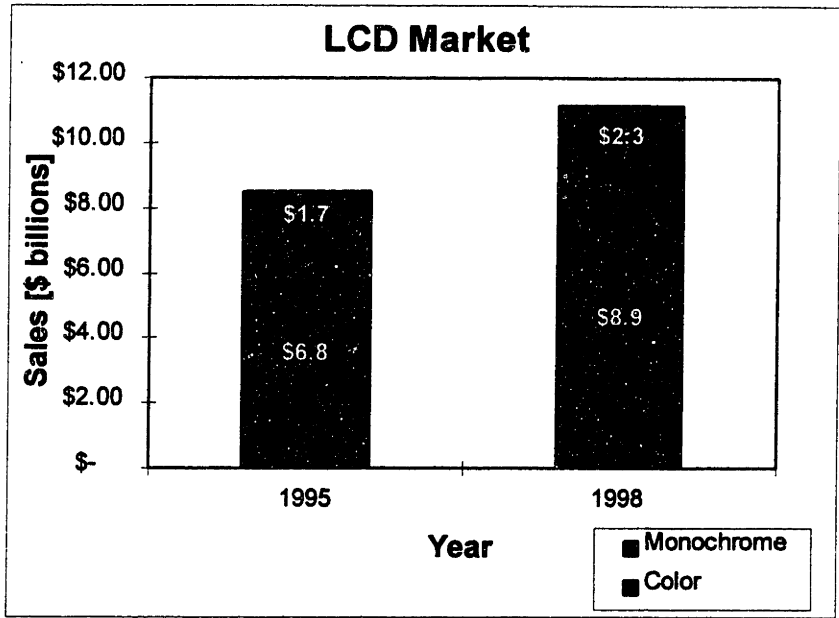


Figure 2.8: Liquid Crystal Display (LCD) Market

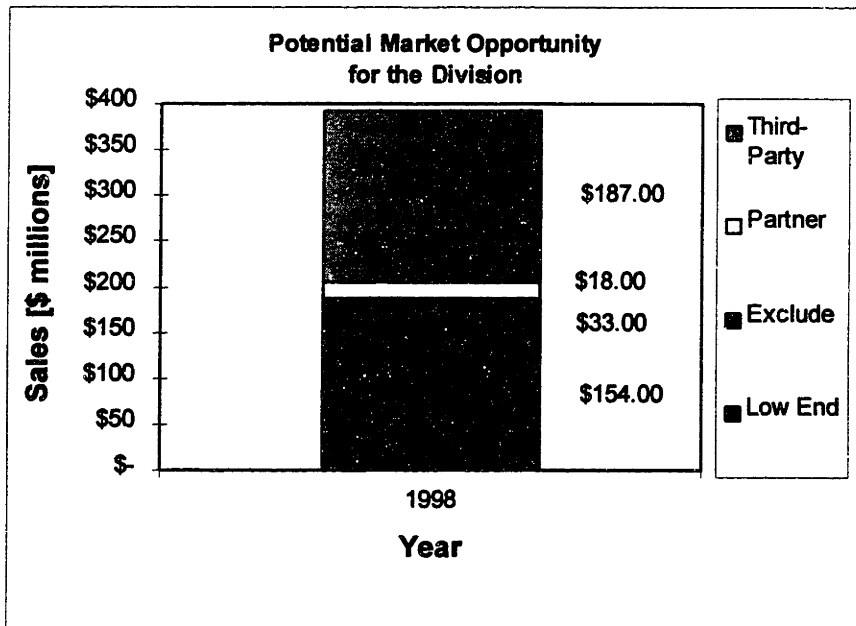


Figure 2.9: HPD's Potential Markets for Imagix®

2.4.1 Competitive Issues

For the past few years, HPD has felt competitive pressure on price and product configuration in the display businesses. The cost of HPD's volume-phase holograms was greater than embossed holograms or traditional print media. The use of holograms for authentication and promotional material sometimes required much thinner configurations than could be made using HPD's patented photopolymer. Embossed holograms were a less expensive alternative for these types of holographic products that didn't require the brightness that volume-phase holograms made with HPD's patented photopolymer provided.

HPD operations were maintained and supported by Polaroid throughout the recent corporate downsizing because holography was viewed as a growth opportunity. In the summer of 1995, the new vice president was hired to drive this growth with profitability. A Polaroid executive vice president commented, "[The new vice president] has an outstanding track record as a general manager. His expertise in identifying potential growth opportunities, improving response time to customers, and increasing operational efficiencies will be an asset to [HPD]."⁶ The new vice president had come from a major appliance manufacturer and was ready to apply his successful approach for manufacturing appliances to HPD's operations. HPD recently received awards for Imagix® and he saw the new display enhancement business as the best opportunity for pursuing profitability.

The original concept for the brightness enhancer was developed by the partner company, which had a patent application on file. HPD felt that licensing from this partner was necessary to retain credibility with third-party customers because of the partner's clout. The strategy was to focus on smaller, high-value products first and to target market leaders by creating a 'pull' from end-users and a 'push' from LCD OEMs. Other specialty material products companies, 3M for example, were developing their own display enhancement technology as well. To date, no other technology is as efficient in managing light. In fact,

⁶ Polaroid press release

holograms made with HPD's patent polymer are estimated to be 10 times as bright as other display enhancement products.

2.5 Problem at Hand

When the new vice president arrived, HPD employed 62 people. A large percentage of the staff supported the display image markets, including its own branded product for the kids retail market. A small proportion of the staff supported the HPD's OEM and industrial products business.

The vice president decided to refocus HPD's business in display enhancement by targeting large industrial customers and security users and pulling out of its house-brand and custom image retail lines. The strengths of HPD's photopolymer product technology were perceived to hold a greater competitive advantage in the display enhancement market. As a result of the business refocusing, the staff was reduced by approximately 30 percent. After layoffs HPD employed 40 people, with most of the layoffs occurring in sales and marketing. Some staff were reassigned to support the OEM/industrial business and to improve manufacturing operations. HPD stressed it was not abandoning the display market and was committed to delivering quality holograms in a timely fashion to long-time customers with good paying histories.

With the layoffs, some of the original technicians who developed the "art" that the manufacturing system was based on were lost. Because of HPD's informal communication style, much of the tacit knowledge related to holography manufacturing was lost with them. To transform the job-shop manufacturing system into a specialized manufacturing system, much of this tacit knowledge was needed. How could the remaining organization develop the required knowledge quickly?

HPD had already started production for its partner and a few other third-party customers. Sales were growing rapidly and the salespeople had committed manufacturing to a very tight schedule. How should the vice president design the organizational structure and incentive

systems to support the business commitments and technology development? Polaroid wanted to see profitability from HPD as soon as possible, so how could the vice president and product development manager get the most out of the available resources for immediate operating activities and future technology development activities?

2.6 Summary

As a result of the reorganization and refocusing, the people were becoming very confused and mainly concerned with job security. At first I couldn't understand why no one was focusing clearly on the business strategy and adapting the manufacturing strategy more quickly. My initial assignment with HPD was with the manufacturing tool team. I was assigned to this team because it was perceived to be the main cause of quality problems. As I gained a better understanding of HPD's business situation and its manufacturing capabilities, I realized there was a deeper, systemic cause of the problems.

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3. Process Development for Manufacturing Capability

A firm's process development capability can play a very important role in creating competitive advantage in the material and chemical industries. Process development is the source of new manufacturing capabilities that enhance a business strategy. In the past, innovations in material or chemical technology may have been sufficient to secure a patent and a comfortable market position, but today's competitive environment requires a stronger defense because there are more entrepreneurs ready to innovate around a patent.

Organizational capabilities vested in the process development function can provide advantage through lower cost, better quality and reliability, and greater operational flexibility.

This chapter describes the process development capabilities of HPD and a methodology for enhancing these capabilities. The current process development capability at HPD is described through my efforts to develop a manufacturing strategy for the industrial product needs. In my endeavors to complete a process development study, I experienced some organizational obstacles, both formal and informal, that suggest HPD does not value process development activities.

3.1 HPD's Manufacturing Capability

Pursuing the industrial products business requires HPD to develop complementary manufacturing capabilities. HPD's strategy for developing the needed capabilities is not defined and the process development efforts lack leadership. In fact, only the formal reward system and the fear of losing a job are motivating the workers to improve HPD's operational effectiveness in pursuit of profitability; this approach to process development will only build manufacturing capability slowly and indirectly. The HPD culture is not well suited for the activities of continuous improvement and process development because of an ingrained technology-driven culture – a culture that only values innovations in product technology.

The shift in HPD's product strategy is depicted in a product-process matrix⁷ below [see Figure 3.1]. The most efficient positions on this matrix are along the diagonal. Positions above the diagonal result in chaotic operations and positions below the diagonal result in wasted effort.

Product Structure; product life cycle stage				
Process Structure; process life cycle stage	I. Low volume - low standardization, one of a kind	II. Multiple products low volume	III. Few major products higher volume; some standardization	IV. High volume - high standardization, commodity products
I. Jumbled flow (job shop)	display products operation	(product focused strategy)	unfocused manufacturing operation	
II. Disconnected line flow (batch)		(comprehensive strategy)	(process development)	
III. Connected line flow (assembly line)			industrial products operation	
IV. Continuous flow				

Figure 3.1: Product-Process Matrix Map for the Holographic Products Division

Note: Adapted from "Link Manufacturing Process and Product Life Cycles," by R.H. Hayes and S.C. Wheelwright in the *Harvard Business Review*, January-February 1979 (p. 135).

Because HPD has quickly shifted its product focus to the industrial product family without an accompanying development in manufacturing capabilities, its operations are now somewhat chaotic. Through process development activities the organization can develop the

⁷ R. Hayes, S. Wheelwright, and K. Clark, *Dynamic Manufacturing: Creating the Learning Organization*, (Free Press, New York, 1988).

capabilities needed for an efficient operation that supports the new product strategy. If a complementary manufacturing strategy had been developed along with the industrial business strategy, a more direct path to efficiency could have been followed and HPD's strategic position would be secured sooner.

The current manufacturing system is not appropriate for meeting the demands of the industrial product family. A systematic approach needs to be taken to evaluate manufacturing strategy for meeting future demands. The initial objectives of my internship were:

- to determine key process parameters in chemical processing that affect product durability,
- to develop a process model to be used for evaluating manufacturing policies, and
- to develop an idealized design of a manufacturing system that meets the needs of the Imagix® product family and evaluate implementation strategies.

3.2 Developing a Manufacturing Strategy for HPD

Before 1996, there was no formal approach to developing a manufacturing strategy for HPD. The current machine used for conditioning, exposing, and chemically treating the holographic sheet had evolved out of the 13 years of experience. Typical product development was carried out using a "hand copy" process for making holograms; this manual method was very operator dependent. After a few years, a pilot machine was developed for automating the process. The automated pilot process integrated HPD's experience of the "hand copy" process with the corporate experience in coating and sensitizing photographic film. Over the years much experience was accumulated by technicians and research holographers in HPD. The design of the current production machine, called HP-1, was based on this experience. The development of this experience base and transfer of knowledge to manufacturing was completed in a very casual way with very little strategic direction, other than the desire to make neat holograms.

3.2.1 Planning as Strategy

As markets have gradually become more competitive, management processes have replaced the leadership roles of past visionaries. The quest for productivity, quality, and speed has resulted in a number of management tools and techniques such as: total quality management (TQM), benchmarking, and reengineering. These management processes can be uninspiring and ineffective when used in isolation, especially in the area of manufacturing strategy and production planning. Russell Ackoff, author of Creating the Corporate Future, talks about three typical management styles – reactive, inactive, and preactive – and introduces a fourth – an interactive methodology. Ackoff argues that in today’s competitive and technically complex environment, the traditional methodologies are uninspired and that management can be more effective using an interactive approach.⁸

A reactive management style is a bottom-up approach with the main goal of restoring a past situation; this style is very operative and hopes to restore the peace. An inactive management style is a crisis management approach, which tries to avoid errors of commission. Preactive management is a top-down approach to strategic planning; it aims to predict and prepare the organization for a forecasted future. Interactive management involves designing a desirable future and making it a reality through directed organizational learning.

Interactive planning is a holistic approach to selecting or designing an ideal system for the organization’s purposes. The process of interactive planning should be participative in order to provide continuity and integration with all aspects of the organization. The approach to interactive planning involves formulating the problem, selecting the desired ends, identifying the means, planning for resources, and designing a strategy for implementation and control.

Managing interactively requires managers to have new skills. Interactive managers must be able to lead their organizations in defining an idealized design and to motivate the workers in finding the shortest path to the desired ideal state. In motivating workers, managers should

⁸ R.L. Ackoff, LFM ProSeminar Video, 1989.

realize there are three types of outcomes people pursue: goals, objectives, and ideals. Goals are ends that can be attained within a given period. Objectives are ends that aren't expected to be attained within a given time period, but toward which progress can be made. Ideals are ends that are believed to be *unattainable*, but towards which progress can be made.

The interactive manager has four types of planning available to him for pursuing desired outcomes: operational, tactical, strategic, and normative. Operational planning is selecting the means for pursuing goals. Tactical planning is selecting the means and goals for pursuing objectives. Strategic planning is selecting the means, goals, and objectives in pursuit of a set of ideals. Normative planning is the explicit selection of means, goals, objectives, and ideals.⁹

3.2.2 HPD's approach to manufacturing strategy

When I arrived at HPD, there was a very mixed management style because the organization was in transition. Just a few months prior to my arrival the manufacturing manager had transferred to another division and an interim manager had been designated. Also, the long standing general manager had recently retired and a new vice president was about to start. When I was there, the interim manufacturing manager took a crisis management approach – possibly because of the recent quality problems. The operators and supervisors who had been in place for some time were more reactive in attending to daily operational issues.

HPD manufacturing held daily operations meetings to review the previous day's activities and plan the current days activities. Weekly and monthly plans would be made, but these long-range plans were changed daily. Other than these operations meetings, there weren't any resources for production planning, manufacturing strategy, or process engineering. The holographers and chemists in research and development would occasionally notify manufacturing of a new process they had used in the lab, but manufacturing typically did not trust lab results to be indicative of results that could be expected in production and therefore did not implement lab designed processes.

⁹ R.L. Ackoff, Creating the Corporate Future (John Wiley & Sons, Inc., New York, NY, 1981).

While at HPD, I participated on two process improvement teams and one product development team. The HPD organization viewed me as an “outsider,” able to provide an unbiased evaluation of their business and operating situation. I was not able to become an “insider” because I wasn’t accustomed to the strong culture, which was changing as a result of the tumultuous atmosphere.

3.2.3 The Manufacturing Tools Team

The manufacturing tools team was the first process improvement team I worked on. The purpose of this team was to improve the quality of tools being made for hologram manufacturing. The tool specifications for industrial products manufacturing were not very well defined and the manufacturing operators insisted it was the major source of the product quality problems. A process engineering approach to understanding how the tool-making process created final tool quality and to identifying key tool characteristics that were important in the process of making high quality holograms was needed. This process engineering approach requires examining the function of the tool to identify key characteristics and then modeling each unit operation of the tool-making process to understand how process parameters affect final tool quality.

As part of this team, I helped to identify a key characteristic that indicated the tool quality and expected usefulness for manufacturing. Because there were limited resources for experimentation and modeling of the tool-making process, a continuous improvement approach was taken. Using TQM principles, I developed a database for determining the appropriate statistical process control (SPC) methodology that would facilitate continuous improvement in the tool-making process [see Appendix A]. The SPC analysis indicated that the tool manufacturing process produced tools with a standard deviation of 33 percent for a key characteristic. Outside of a 3 sigma range, the process appeared to be out of control resulting in tools with greatly diminished useful life. Approximately 15 percent of the tools produced are outside of a 3 sigma range around the mean of the key characteristic. If these

tools were identified and scrapped before the final tool finishing step, a savings of 20 percent could be realized and the average useful life of a tool would increase by 10%.

Unfortunately, the manufacturing organization was quick to say the SPC methodology was not picking up the subtleties of the tool quality. They wanted a technological, quick-fix to the tool quality problem. At this stage I realized that the HPD culture did not value an empirical approach to problem solving and developing process knowledge.

The experience I had with this team was very informative. I met a variety of people from various functions (manufacturing, research, and development) within HPD. Through participation on this team I learned how the various functions of the HPD organization worked together. Their interactions were amicable, but not very collaborative. For example, even though development felt there were bigger causes of poor quality than the tool, and considering that manufacturing wouldn't give development any resources for its efforts, development still attempted to solve the problem as manufacturing saw it. This experience showed me that HPD needed to develop a systems perspective and could benefit from a systems engineering approach to process design.

"Systems engineering is concerned with the design, modeling, and analysis of technological systems that use people and machines, software, and hardware, material, and energy for such purposes as communications, health care, material and energy, and manufacturing."

Chapman et al.¹⁰

The manufacturing tools team didn't talk explicitly about how the system as a whole could be improved. Instead, the team's efforts were directed at trying to get around the system problems by finding a new material for the tool, or building new facilities, or restricting extraneous people from process areas. For the first couple of months, no measures were implemented to monitor the quality of the material, or the facilities, or the peoples' performance – which could be used for process control. When a measure was suggested it

¹⁰ Chapman, W.L., A.T. Bahill, and A.W. Wymore, Engineering Modeling and Design (CRC Press: Boca Raton, FL, 1992).

took several weeks for the manufacturing personnel to adopt the practice of monitoring and using these new control variables.

3.2.4 The Manufacturing Process Improvement Team

Another team I participated on was the manufacturing process improvement team. This team was a special task force assembled to achieve quick gains in the manufacturing quality and efficiency, and quick reductions in variability. The team consisted of process experts from outside the HPD organization. Several of the team members were recent retirees as a result of the latest corporate downsizing. The fact that this special task force had to be created from retired Polaroid employees showed again that the current organization didn't have the required process development capabilities for creating manufacturing processes that would support the business strategy.

The short-term goals of the team were met and manufacturing reliability was moderately improved so that key deliveries would not be too late. A longer-term program for variation reduction was initiated by this team with process mapping and identification of process parameters, but the effort faded because the holography organization didn't have the learning capabilities needed to support this program.

Realizing that HPD needed to expand its manufacturing capabilities in support of the industrial products business strategy, I proposed a systematic evaluation of manufacturing strategy alternatives. These manufacturing strategy alternatives would be developed with a cross-functional team, representing the various technical competencies held within Polaroid.

Using the approach developed by Ackoff, I attempted to create an idealized design for manufacturing HPD's industrial products. I would then model the idealized design and evaluate various strategies for implementing this design. To support the development of an idealized design, HPD needed better process knowledge. The current manufacturing operation seemed too much like a craft rather than a scientifically defined process for producing highly uniform, holographic products. HPD needed to complete some process

characterization to identify key process parameters that could be used to control the key product quality characteristics. I proposed to do this process characterization using lab experiments and tests in the manufacturing environment.

My initial proposals for process characterization and creating an idealized design were accepted by the HPD organization as good activities to pursue, but deep down the HPD culture did not value process development activities and the empirical approach to problem solving. The lab and pilot facilities had not been kept up to date and the manufacturing supervisors didn't trust any data using the lab and pilot equipment. Furthermore, the manufacturing schedule was overbooked and the machine reliability was very poor, resulting in no time available for conducting experiments in the manufacturing area.

In creating an idealized design, I interviewed three senior managers to understand their needs and get their commitment to my program, but they weren't able to commit specific people on my team. Also, if people from other divisions were to help me out there would have to be a cross charge, but I wasn't given a budget for such charges. A key obstacle to this approach was that the current manufacturing organization was in a crisis mode of operation. Also, the reorganization had severely limited the resources available for process development activities. Furthermore, the idea of freely accessing technical experts from other divisions was not easily adopted.

3.2.5 The Product Development Team

The main objective of this product development team was to improve product durability. The product durability resulting from the current process was highly variable and occasionally the product met the desired durability goal. There were two approaches to improving the durability. One approach involved designing a new protective coating to add to the product. The other approach was to define the control parameters for the chemical treatment steps and design operational procedures that would provide higher durability with reduced variability.

The high variability in product durability was the result of a very complex, interacting system of the machine, the holographic film, the chemicals used for treatment, and the manufacturing environment. The HP-1 machine used by manufacturing continuously pulled a roll of photo-polymeric film through environmental conditioning chambers, imaging chambers, and chemical baths [see Figure 3.2]. HP-1 was operated in a semi-batch mode. For the industrial products, rolls had to be passed through HP-1 twice. The chemical baths would be filled at the start of a run, and were recirculated and filtered throughout the run, but they were not replenished with active chemicals during a run. Batch sizes were typically dictated by the size of a customer order, which was generally shorter than the useful life of the chemical baths. Batch sizes for the industrial product were typically much longer than the useful life of the chemical baths; this is where the quality problems started to occur.

The many unit operations (i.e., conditioning, imaging, and chemical treating) of the manufacturing system interact and affect the final product quality in a confounded manner; this is referred to as the quality roll-up problem. Through characterization of the individual process operations that comprise the manufacturing system, key parameters can be identified that are significant contributors to the final product quality. An understanding of how the key parameters interact and contribute to quality allows the manager to evaluate short-term operational decisions and long-term manufacturing strategies more effectively. Through analysis of the chemical and polymerization reactions, key process parameters can be identified and tested with experimentation to develop a quality roll-up model.

When I first joined the product development team, I presented a formal proposal of the process characterization activities I wanted to pursue and the quality roll-up model I expected to build. After my presentation, I felt the group did not know how to react to my formality and they neglected to raise any issues that might complicate the proposed activities. The rest of the group promptly forged ahead in exploring new protective coatings while I was given mild encouragement in my pursuits of process characterization.

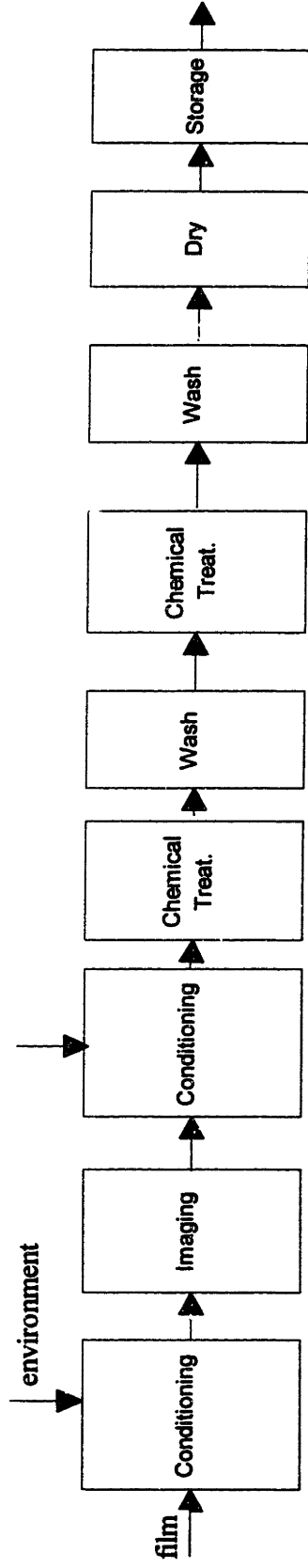


Figure 3.2: General HP-1 Process

My objective was to model the quality characteristics of product durability as affected by: pH, an alternative chemical treatment/wash, and the water content of the film during exposure and chemical treatment. The desired model would include operations/physical transformation variables (i.e., exposure energy and time, chemical treatment time, film tension), state variables (i.e., active chemical concentration, contaminant concentration(s), temperature, pH), control variables (i.e., temperature, pH, humidity), and measurement variables (i.e., reflectance, color, chemical composition, contact angle) [see Figure 3.3].

The end goal of developing a quality roll-up model is to describe the root causes of quality issues in the manufacturing system and to determine optimal operating, scrapping, and maintenance policies. The complex task here is elucidating the interactions of control parameters at one stage with the quality state of downstream stages of the process. This modeling approach should incorporate both statistical- and physical-based knowledge.

3.2.5.1 Background on Holographic Photopolymer

The holographic film used by HPD to record holograms is composed of a film-forming polymer, a photo-initiation system, and monomers. After exposure, the film contains a record of the light interference pattern reflected off a three-dimensional object as a spatial variation of its chemical composition. The light interference pattern is a pattern of high intensity light and no light. When the high intensity light shines on the holographic film, the photo-initiator is activated and a polymerization reaction occurs. Relatively high polymer concentration is found in the regions that were high intensity light during the holographic exposure, and low polymer concentration is found in the surrounding no light regions, resulting in a refractive index change.

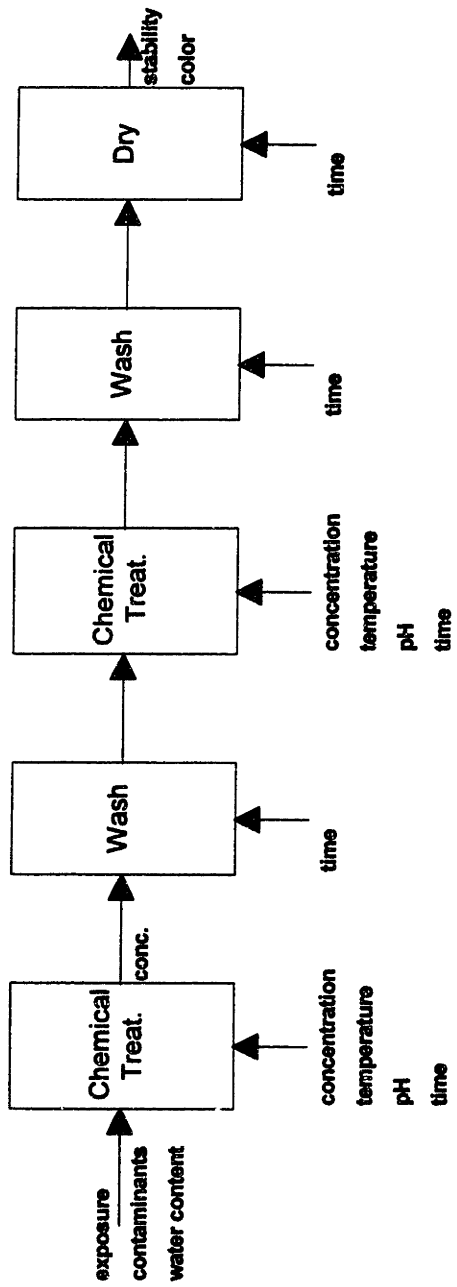


Figure 3.3: Quality Roll-up Model of HP-1 Process

Forty percent of the volume of the hologram is calculated to be void or airspace; this void-space makes the hologram susceptible to degradation in various environmental conditions. Differential swelling, phase separation, and dissolution of soluble components during chemical processing may all contribute to pore formation. The durability of this porous polymeric structure is affected by chemical crosslinking and the deposition of a hydrophobic layer on the surface of the hologram.

3.3 Summary

Looking back at the experience of others, I saw that the organization historically relied on product innovations rather than incremental process innovation for solving problems. My experience with the manufacturing tools and manufacturing process improvement teams showed that technical knowledge was held by dispersed individuals and learning was adaptive, not generative. The organization needed to learn how it could operate in a different way under this new reality.

From these experiences, I learned the organizational culture didn't support an empirical methodology to problem-solving and learning – they preferred neat technology solutions. This revelation convinced me that the organization wasn't conditioned to operate effectively in this new reality of constrained resources and the pursuit of a standardized manufacturing system with high operational effectiveness.

4. Managing Manufacturing Capabilities

The role organizational capabilities, resources, and other firm-specific assets play in creating a firm's competitive performance has been well researched.¹¹ An appropriate set of organizational capabilities to consider when developing a firm's strategy includes innovating and applying product technologies, identifying customer segments, establishing distribution channels, and developing manufacturing processes. If a complete set of complementary capabilities is not available to a firm it can be very difficult to establish a sustainable competitive advantage. In particular, a firm's process development capability can play a very important role in creating competitive advantage in the material and chemical industries.

This chapter presents the concepts of manufacturing strategy and a framework for managing the process knowledge that is needed to develop a strategy. This framework is a combination of research from the fields of strategy and innovation.

4.1 A Framework for Developing a Manufacturing Strategy

4.1.1 *Use a Comprehensive Strategy to Motivate Operational Effectiveness*

It can be argued that in some companies today, management tools and processes have taken the place of strategy. In defining a company's competitive strategy, Porter argues that it is the general manager's job to define and communicate the company's unique position and the set of activities that embody the organization's distinctive capabilities.¹² By performing activities differing from competitors, a company can secure its strategic position by delivering greater value to the customer. The set of activities that defines the strategy must include the operational activities that are complementary and reinforcing of the business activities.

¹¹ see Teece, 1982; Hayes, Wheelwright, and Clark, 1982; Prahalad and Hamel, 1990; Chandler, 1990; and Porter, 1996

¹² M.E. Porter, and C.R. Christensen, "What is Strategy?" *Harvard Business Review*, November-December 1996, pp. 61-78.

Strategic positioning can be based on providing customers variety, serving customer needs, or accessing customer segments. HPD is shifting its positioning from providing variety to serving needs, but has not developed the complete set of activities or organizational capabilities needed to support this change in strategy. Key choices need to be made clearly in the area of HPD's manufacturing capabilities. Tradeoffs must be made to avoid image inconsistencies, system inflexibilities, and coordination and control limits. The pursuit of operational effectiveness is seductive because it is concrete and actionable.

Operational effectiveness refers to any number of practices that allow a company to better utilize its inputs by reducing defect or accelerating product development. By pursuing improved operational effectiveness, a company realizes efficiency gains that result in lower unit costs. Constant improvement in operational effectiveness is necessary to achieve superior profitability, but a competitive strategy requires making tradeoffs to choose a complete set of activities that deliver a unique mix of value.

While operational effectiveness is about achieving excellence in individual activities, or functions, strategy is about *combining* activities. Activities must fit simply so that implementation is single-minded. The results of an unclear shift in strategy are inconsistency across functions and organizational dissonance. Companies that try to be all things to all people risk confusion. The essence of strategy is choosing what not to do. When companies operate far from the productivity frontier, tradeoffs appear unnecessary.

A company's core uniqueness can be identified through the following questions:¹³

1. Which of our products or service varieties are the most distinctive?
2. Which of our products or service varieties are the most profitable?
3. Which of our customers are the most satisfied?
4. Which customers, channels, or purchase occasions are the most profitable?
5. Which of the activities in our value chain are the most different and effective?

¹³ Ibid.

The integration of complex technologies can be difficult and may slow down product and process innovation. Managers must make a tradeoff between speed and quality design and understanding that rushing a new product family to market may be fruitless if the appropriate organizational and operational capabilities are not in place to support competitive performance. Meyer and Utterback¹⁴ explore the factors that determine success in product development and conclude that forcing development when there are technological and market uncertainties can produce failure. They present a method for mapping out an organization's evolution of product families and assessing the underlying core capabilities. They have found that higher levels of core capability tend to precede and coincide with higher levels of performance.

4.2 Managing Process Development for Strategic Advantage

Process innovation does not only concern designing the process, but also implementing and replicating it within the firm's operating environment. If organizational capabilities are embedded in routines, then how firms go about designing, implementing, and replicating such routines must be a central facet of organizational learning. The learning curve reflects only a narrow slice of the broader phenomenon of organizational learning.

4.2.1 *The Abernathy-Utterback Model of Innovation*

The Abernathy-Utterback model of innovation recognizes two major waves of evolutionary development [see Figure 4.1]. The first wave is dominated by product innovations and the second by process innovations. These waves of innovation result in three phases of product development – a fluid phase, a transitional phase, and a specific phase. Progression through these phases results in a shift of the basis of competition from performance and technology to price and cost. This shift is usually accompanied by an expanding market, increasing

¹⁴ see M.H. Meyer, and J.M. Utterback, "The Product Family and the Dynamics of Core Capability," *Sloan Management Review*, Spring 1993, pp. 29-47; and M.H. Meyer, and J.M. Utterback, "Product Development Cycle Time and Commercial Success," *IEEE Transactions on Engineering Management*, November 1995, vol. 42, no. 4, pp. 297-304.

importance on investment in manufacturing processes, and a progression from radical to incremental innovation.

The fluid phase of the Abernathy-Utterback model is characterized by competition between a few distinct product designs, where functional performance is key and product changes are made at relatively low cost; manufacturing methods are flexible but inefficient and use generally established process technology. For nonassembled product, the transitional phase switches to more specialized manufacturing processes possibly including automation, where the ultimate outcome is most often a continuous process. The combining of multiple processing steps into one step of a larger scale operation and productivity gains are the result of process innovation. In the specific phase, competition is more value oriented and most innovations are aimed at increasing the customer's perceived value. Product and process innovations in the specific phase become incremental because of the high cost associated with fundamental changes, and they become more tightly bound to one another.

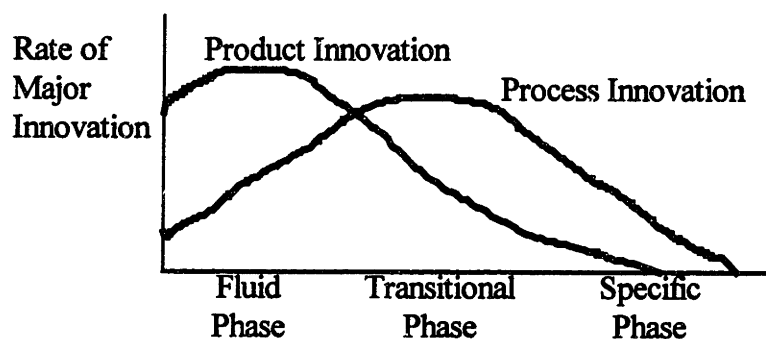


Figure 4.1: Abernathy-Utterback Innovation Model

The Abernathy-Utterback model draws primarily from markets for which cost and performance are the commanding factors, rather than from markets where fashion, novelty, or advertising are important competitive variables. The cost and performance requirements force an evolution in product design from a few distinct designs to one dominant design. Consideration of how technologies advance is also important to consider within this

framework. Utterback¹⁵ refers to work by Philip Anderson and Michael Tushman that describes a technological cycle for assembled products where a technological discontinuity is followed by an evolution from which a dominant design emerges. For non-assembled products it is often the case that an enabling technology creates the opportunity for a new product. This dramatic change in process architecture is followed by an era of incremental change during which the dominant design is elaborated [see Figure 4.2]. In comparing assembled and non-assembled products we might easily substitute the term enabling technology for dominant design.

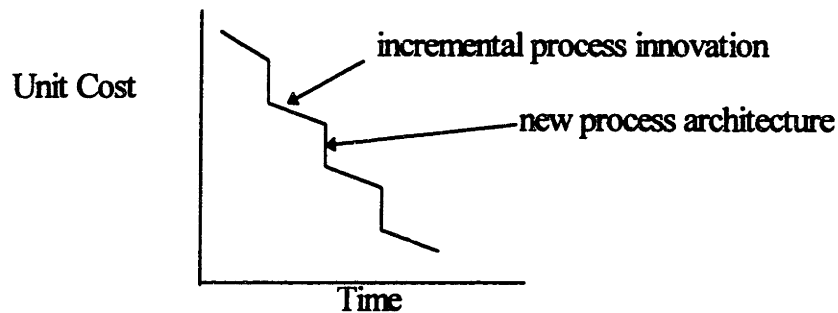


Figure 4.2: Enabling Technologies and Process Innovation

Utterback emphasizes that it is essential for innovators to understand the interdependencies of product technology with the manufacturing process, the corporate organization and strategy, and the structure and dynamics of an industry.

A cost/benefit analysis identifies four factors through which process innovation can provide an advantage: 1) cost of developing a new process, 2) level of monopoly profits in the market for the product, 3) level of monopoly profits in the market for the process, and 4) the volume of products likely to be made using the new process. To the extent that companies can appropriate innovations through patents, first-mover advantages or downstream assets, they can also shelter more productively their investments in innovation. It is tempting to suggest

¹⁵ J.M. Utterback, Mastering the Dynamics of Innovation: How Companies Can Seize Opportunities in the Face of Technological Change (Harvard Business School Press, Boston, MA, 1994).

that process innovations can provide greater appropriability of innovation, but often there is a high cost associated with introducing process innovation. Process innovations hold out the promise of major productivity gains, but at staggering costs.

In the pharmaceutical industry, for example, monopoly position has been created and maintained through patents. The growing number of technologies available for administering therapies may reduce the appropriability realized through product patents and require firms to discover process innovation as another way for appropriating the profits from innovation. Pharmaceutical manufacturers can, of course, benefit from process innovations in raw material, capital, labor, and energy savings, but more importantly from improved patent position and competitive advantage in the product development race.

There are competence-enhancing and competence-destroying innovations and managers must identify which innovations to commercialize and when to build new competencies in anticipation of future developments.¹⁶ Companies that possess the capability to bring technology to market can drive out competitors. Success lies in using innovations in products across a wider range of markets and in integrating them with a breadth of other technologies.¹⁷

A critical decision concerns when it becomes worthwhile to commit to an investment to commercializing process innovations. An easy answer is provided by economic analysis, which states that firms should continue to operate with existing technology as long as marginal costs are covered. This is an inadequate short-run answer in the context of an industry undergoing rapid and uncertain technological change.¹⁸ Through process innovation,

¹⁶ Ibid.

¹⁷ T.M. Nevens, G. Summe, and B. Uttal, "Commercializing Technology: What the Best Companies Do," *Harvard Business Review*, May-June 1990, pp. 154-163.

¹⁸ Landau, Ralph and Nathan Rosenberg, "Innovation in the Chemical Processing Industries," paper from Technology and Economics: Papers Commemorating Ralph Landau's Service to the National Academy of Engineering (National Academy Press, Washington, D.C., 1991).

the chemical industry has produced innovations that result in products that are not only of better quality but also are more precisely configured and differentiated to cater more effectively to specific categories of consumer needs.

Success in the commercialization of chemical process innovations has depended critically upon the productivity gains realized through an improvement process that takes place after the innovation is introduced in the market. In the pharmaceutical industry, process innovation has typically only been introduced if it provided any added patent protection. The competitiveness of pharmaceutical firms has been dependent upon the effectiveness of a firm's basic research organization to identify potential therapeutic compounds.

The future competitiveness of pharmaceutical firms will be more dependent on many other activities downstream from the basic research process. Firms that have the ability to develop process technology and utilize it to design quality into products and processes will gain a competitive advantage. Process technology can be used to enhance profits by increasing revenues as well as decreasing costs. Integrating process innovation earlier into the product development process can speed up new product introduction and increase customer satisfaction through advantages in cost, quality, and flexibility.

Over the past 15 years, many companies have learned it is expensive and misguided to inspect for quality rather than design for quality in the process. Some companies with integrated product and process technologies realize opportunities to control products cost because they are more strongly tied to the design. These companies have learned to value new technology developments over the life cycle of the whole product family rather than on the product initiating the development.¹⁹

¹⁹ R. Cooper, and W.B. Chew, "Control Tomorrow's Costs through Today's Design," *Harvard Business Review*, January-February 1996, pp. 88-97.

The biggest obstacle to commercialization of product innovation is implementing the processes needed to duplicate the innovation in a manufacturing setting. Pisano²⁰ has looked at the broad issue of how organizations create, implement, and replicate new routines through process development activities. How organizational capabilities are developed and embedded into routines for designing, implementing, and duplicating innovations are the crux of organizational learning.

4.2.2 Process Development is the Origin of Organizational Learning

The aim of process development is to learn and develop technical models for predicting how different operational choices affect operating performance. There are two strategies for learning: learning-by-doing and learning-before-doing.²¹ When technical process knowledge is low, models are inadequate and experiments must be conducted in the actual production environment – learning-by-doing. Only when technical process knowledge is high can lab models be used to accurately design manufacturing processes – learning-before-doing.

Process developers start with a set of targets for process performance: unit cost, capacity, yields, quality levels, critical tolerances, or other operating characteristics. A process technology is the embodiment of a set of technical choices in an operating routine. Thus process development can be thought of as the activity that creates organizational routines that determine the organization's manufacturing capability. Cross-functional integration of R&D and manufacturing is crucial to successfully performing the process development activity, because the technical choices are tightly integrated with the resulting operating performance. Organizational learning is a problem-solving process triggered by gaps between actual and potential performance

²⁰ Pisano, G.P., "Knowledge, Integration, and the Locus of Learning: An Empirical Analysis of Process Development," *Strategic Management Journal*, 1994, vol. 15, pp. 85-100.

²¹ *Ibid.*

In turbulent environments there is strategic value in being able to develop new capabilities rapidly, to close the gaps between desired and actual performance. In environments where technology is more of an 'art' than science, resources that support learning-by-doing capabilities are very valuable. For managers to be more effective in monitoring and directing the organization's knowledge and process development activities, a clear framework is useful.

4.3 Framework for Managing Technical Knowledge

As knowledge becomes "the one sure source of lasting competitive advantage,"²² managers responsible for setting the strategy need a better tool for measuring and managing knowledge. In technically complex markets where the successful integration of disparate technologies determines success, managers need to understand how their organization's manufacturing capabilities must support the business strategy and provide a clear direction for improving and managing the technical knowledge base that determines the manufacturing capabilities.

Bohn has developed a framework for managers to use in evaluating levels of knowledge and mapping out operational capabilities that result.²³ This framework is predicated on the notion that the key operational and managerial activities are determined by the level of knowledge and that better knowledge can lead to improved capabilities without capital investment, because knowledge enables modeling for testing and prescribing decision.

Technical or process knowledge is an understanding of the effects of input variables on the process output. Better knowledge enables effective process control. Bohn has defined eight stages of knowledge:

²² I. Nonaka, "The Knowledge-Creating Company," *Harvard Business Review*, November-December 1991, pp. 96-104.

²³ R.E. Bohn, "Measuring and Managing Technical Knowledge," *Sloan Management Review*, pp. 61-73, Fall 1994.

Table 4.1: Stages of Knowledge*

STAGE OF KNOWLEDGE	OPERATIONAL CAPABILITY	FORM OF KNOWLEDGE
COMPLETE IGNORANCE	variables appear as random disturbances	Nowhere
AWARENESS	can't use variable in process	Tacit
MEASURE	alter process in response	Written
CONTROL OF THE MEAN	quantify impact on process	Written and embodied in hardware
PROCESS CAPABILITY	control of variance	Hardware/operating manual
PROCESS CHARACTERIZATION	can fine tune process	Empirical equations (numerical)
KNOW WHY	develop scientific model	Scientific formulas and algorithms
COMPLETE KNOWLEDGE	never reached in practice	All-knowing God

* Adapted from R.E. Bohn, "Measuring and Managing Technical Knowledge," *Sloan Management Review*, pp. 61-73, Fall 1994.

Learning from stage I to II occurs by serendipity. Analogy to seemingly unrelated processes and outside knowledge inspire the discovery of process variables. In advancing from stage II to stage III knowledge, learning can be passive or proactive in the study of ways to control the variable. Once stage III knowledge is developed, controlled experiments can be performed to determine the dynamics of the variable. Learning from stage IV to V enables the control of disturbances that affect the input variable. Stage VI knowledge leads to reduced costs and desired product characteristics. The final stages of learning involve forming scientific models, running broad experiments across multiple variables to estimate models, and finding interactions among input variables. The theories of organizational learning say that learning can be a directed activity, not just a by-product of normal production.

Managerial decisions affected by the stage of process knowledge are methods of organizing, problem solving, learning, and training as shown in Table 4.2 following:

Table 4.2: Framework for Managing Technical Knowledge*

Level of Knowledge:	1	2	3	4	5	6	7	8
Nature of production	expertise based		↔		procedure based			
Role of workers	everything		problem solving		learning and improving			
Location of knowledge	workers' heads		oral → written		in databases or in software			
Nature of learning	artistic		natural experiments		controlled experiments, simulations			
Nature of problem solving	trial and error		scientific method		table look-up			
Method of training new workers	apprenticeship, coaching		↔		classroom			
Natural type of organization	organic		mechanistic		learning oriented			
Suitability for automation	none		↔		high			
Ease of site transfer	low		↔		high			
Feasible product variety	high		low		high			
Quality control approach	sorting		statistical process control		feed forward			

*Adapted from R. Jaikumar, "From Filing and Fitting to Flexible Manufacturing: A Study in the Evolution of Process Control" (Boston: Harvard Business School, working paper, 1988).

The benefits of this knowledge management framework are many. Using this systematic approach helps the manager to understand what is known and what isn't known and which variables provide the most leverage. This framework provides a check on the consistency of current management methods with the stage of knowledge and suggests how to manage the process at the present stage of knowledge. It also identifies critical process areas that need

more learning and ways to direct the learning activities. In all, better knowledge of key process variables can lead to better operational performance without incremental physical investment.

Current technical process knowledge in HPD is at stage II or III. This low stage of knowledge is the result of trial and error experiments; assumptions primarily based on failures rather than successes; a low level of accountability, communication, and system perspective; and a pervading Polaroid culture that relied on learning from the top and reaction at the local level.

4.4 Summary

“Knowing how” is partial knowledge and is rooted in the norms and behavior, standards of practice, and settings of equipment; it is part of the organizational culture²⁴ – Polaroid is very good at knowing how to create new product technologies. “Knowing why” is more fundamental knowledge capturing underlying cause-and-effect relationships that lead to modeling for accommodating exceptions, adaptations, and unforeseen events – Polaroid and HPD need to expand their capabilities for knowing why processes make their new technologies.

The HPD organization isn't conditioned to operate effectively in this new reality of constrained resources and the pursuit of operational effectiveness. Most of the current process knowledge is at stage II or III, and the industrial product quality and quantity demands stress the current manufacturing capabilities because a higher stage of knowledge is required. Technical knowledge is held by dispersed individuals and learning is adaptive, not generative. The organization needs to learn how it can operate in a different way under this new reality. Organizational learning can increase the speed and quality of learning, but a supportive orientation and facilitating structures are needed.

²⁴ Pisano, 1994.

5. Understanding the Culture

The holographic film manufacturing system has many areas that need greater technical knowledge to support the development of an ideal system. The individual expertise to address each of these issues resides within Polaroid, but an organizational construct that supports and sustains the needed cross-functional teaming is not well supported. Because of constrained resources, due to the reorganization and an ingrained culture with deeply held mental models, HPD is unable to use its organization effectively to learn and advance its level of technical process knowledge.

Analysis of the Polaroid culture can lead to identification of some shared basic assumptions. Understanding these shared basic assumptions provides the leader with the perception needed to identify functional and dysfunctional elements of the existing organization. Having identified these elements, the leader can better affect cultural evolution to achieve an organization that supports and sustains the cross functional teaming required in the idealized design approach to process development. I performed a culture analysis, as described by Dr. Edgar Schein in Organizational Culture and Leadership, with a HPD product development team. Based on the shared assumptions identified through this cultural analysis, I identified a strategy for developing organizational learning capabilities.

5.1 Background

An excerpt from Polaroid's personnel policies states:

"We have two basic aims here at Polaroid:

One is to make products which are genuinely new and useful to the public – products of the highest quality at reasonable cost. In this way we assure the financial success of the Company, and each of us has the satisfaction of helping to make a creative contribution to society.

The other is to give everyone working for Polaroid personal opportunity within the Company for the full exercise of his talents; to express his opinions, to share in the progress of the Company as far as his capacities permit, to earn enough money so that the need for earning more will not always be the first thing on his mind – opportunity, in short, to make his work here a fully rewarding, important part of his life. These goals can make Polaroid a great Company – great not merely in size, but great in the esteem of the people for whom it makes new, good things, and great in its fulfillment of the individual ideals of its employees."

Edwin H. Land

Founder, Polaroid Corporation

Edwin Land was ahead of his time when he formulated this personnel policy that explicitly states the importance of a work environment that promotes the skills and interest of the employees; this statement established some very strong cultural assumptions. The ensuing experiences of the Polaroid Corporation have created other underlying assumptions that are both supportive and incongruent with what Land initially intended.

5.2 Cultural Analysis

Following Schein's process for working with organizations on cultural issues, I facilitated a group discussion of the three levels of culture (artifacts, espoused values, and basic underlying assumptions) for HPD. The goal of this cultural analysis was to identify important cultural assumptions that aid or hinder HPD's ability to be a learning organization.

The group's main purpose was product development and improvement. There were five people in the group: four employees from development and one representative from manufacturing. The people from development included technicians and Ph.D.-level scientists. The manufacturing representative was a recent retiree from another Polaroid division who had been consulting with HPD manufacturing for three months, but had no direct experience with holography prior to his consultancy. Other representatives from manufacturing were requested to attend this discussion, but the manufacturing manager couldn't spare anyone. Two other senior level managers, who had been with the division one year and 10 years respectively, were invited and initially agreed to participate, but were called away for other business matters.

5.2.1 Artifacts

HPD is a relatively small division within the large corporation. Two weeks before I started, the division's general manager took early retirement and four weeks later a new division vice president started and assumed the responsibilities of the general manager. There were about 60 people employed in the division when I started, but three months into my internship approximately 20 people were laid-off. There were six distinct subgroups that acted somewhat separately. These subgroups were identified as: manufacturing, development, research, marketing, management, and mastering. The majority of the layoffs were in the marketing group. Other cutbacks in overtime affected the manufacturing operators and development technicians who were asked to "help out" in manufacturing.

The people of the division were located in several different locations; this helped to define the subgroups to some extent:

- Most of manufacturing was located in a facility in Waltham, but the mastering subgroup, which was actually a part of manufacturing, was located in the basement of "750 Main Street" – a Polaroid building in Cambridge. Additionally, quality control

(inspection) was located in another building in Cambridge, “38 Henry Street,” but was not identified as a separate subgroup, as it was considered part of manufacturing.

- The development group was located on the first and second floors of another building in Cambridge, referred to as “2 Osborne.”
- The research group that supported development was also located in 750 Main Street, but on the third floor, among many other research laboratories not related to holography.
- The management group was split among many locations. The vice president of the division was in corporate headquarters at Technology Square in Cambridge. The product managers were on the second floor of 2 Osborne and the manufacturing managers were in Waltham. Before the layoffs, the marketing group and its management were located on the third floor of 2 Osborne. After the layoffs, the marketing group moved closer to development.

After discussing several organizational artifacts, it became obvious that the main focus of the group was on differences between “Waltham” and “Cambridge,” which were considered to be manufacturing and development respectively. These two locations made up over 80 percent of the total headcount in the division. The organizational structure of these subgroups was described as being different based on location. Cambridge was described as flexible while Waltham was more rigid. Both locations had operators/technicians, but being a technician in development was more desirable than being a manufacturing operator. There was a modest difference in the average education of manufacturing and development employees. The dress was generally casual, but the senior managers often wore ties and more formal business attire except on Fridays. The scientists and manufacturing supervisors wore business casual clothes, and the operators/technicians wore industrial work clothes. The managers or leaders of Waltham and Cambridge were believed to have different views on the division’s

performance. Waltham's view generally was negative, Cambridge's view was more positive, and it was believed that the rest of Polaroid viewed holography as having a good turnaround.

The method of communication was informal. Often rumors would circulate before a group or division meeting was called to align everybody's understanding of a situation. The communication networks were also affected by the change in executive leadership. The retired general manager was viewed to be more autocratic with very directed communication that let people know what was going on. The new vice president was viewed to be more democratic, but delays in official communications led to leaking of rumors.

The invoice system was not coordinated between sales and manufacturing. Often, in production scheduling meetings there were complaints that sales targets were not matched with manufacturing capabilities. Orders were made with delivery dates that could not be met or quality and shipping requirements that would reduce manufacturing's overall performance.

Although HPD was dependent on manufacturing and committed to improving its operating performance, it relied on just one machine for manufacturing holographic products for its survival. This reliance on one machine that was very unreliable created a lot of stress and a very reactive atmosphere. Furthermore, the facilities weren't believed to be state of the art. The operations were based on knowledge developed internally at Polaroid and were not viewed as being world class.

In the fall of 1996, a new Performance Management Policy was implemented for all of Polaroid that required all employees to have written annual objectives, written performance reviews, and continuous coaching and feedback. Through a process called "Success Management," the company's business direction is translated into written objectives for individual employees; this process is an interactive discussion with the supervisor that results in agreed-upon objectives. CEO Gary DiCamillo supported this policy: "Each of us needs to

know what we are expected to do, if we are going to succeed. Having written objectives helps to keep both supervisors and employees focused on how to succeed and helps ensure fairness in the evaluation.”²⁵ A culture of informal communication was viewed as directly conflicting with this corporate-wide performance policy and bonus plan.

5.2.2 Espoused Values

The overriding belief was that the Polaroid corporate model was the rule. In other words, Polaroid’s functional organization and modes of operation were the only way to be successful. This led to values that production was best achieved with a strict focus on production and little experimentation, and development was best achieved with flexibility.

The Polaroid culture valued neat technology. They believed that the big gamble on new products that would have protected markets was the best payoff and that neat technology would sell itself. The group I worked with mentioned two projects as examples of neat technology that were pursued without a thorough analysis of what the market wanted: Polavision and the digital camera. Polavision was an instant motion picture technology intended to be sold to consumers for making instant home movies. A lot of development funds were invested in this technology, but the product missed its market window when video tape hit the market. The digital camera was something that this group felt wasn’t one of Polaroid’s competencies, but was getting development funds because it was neat technology. The group also stated that no development funds were allocated unless a market was believed to exist. They stated a value for cost effectiveness.

The daily goals of the manufacturing and development groups were somewhat different. Manufacturing was more disciplined and “scheduled,” with goals related to quantity of product shipped, quality, yield, and machine efficiency. Development didn’t have very well

²⁵ *Polaroid Vision*, (a Polaroid newsletter) December 1996.

defined daily goals. The goals for development were of a longer-term nature and generally related to discovering and developing technology for product quality and process consistency.

The new vice president placed more emphasis on profitability, or “making money,” as contrasted with the retired general manager who had more of a scientific background and focused on expanding the product lines and developing the technology. HPD valued short development cycles as a result of the retired general manager’s focus during his tenure. Projects for process improvement, that were of a longer-term nature, were ignored as a result. The new vice president’s emphasis on profitability created a primary concern for increasing production volume and secondary support for activities that improved the quality.

HPD was analytical in its problem-solving approach, but relied on theoretical rather than empirical solutions. In other words, theories about how a neat technology could solve a process problem were valued over statistical process control charts that showed when a process was in control. When individuals developed new theories or discoveries, they were communicated informally. Explicit communication, or formal written reporting, was not valued.

5.2.3 Basic Underlying Assumptions

Throughout my time at Polaroid, no one explicitly mentioned the personnel policy quoted at the beginning of this chapter. It was only when I asked for the corporate mission statement that I was given the policy document. There are two possible explanations for this oversight by the organization: 1) the assumptions of the policy are so ingrained into their daily actions that they aren’t consciously thought of, or 2) there may be some incongruencies in the stated values and initial assumptions with the current operating values and assumptions, and the organization doesn’t want to confront them. Through my discussions with individuals and the product development group, seven underlying assumptions were identified. Based on my

experience with all the subgroups of this organization, I saw the pattern or paradigm depicted in Figure 5.1.

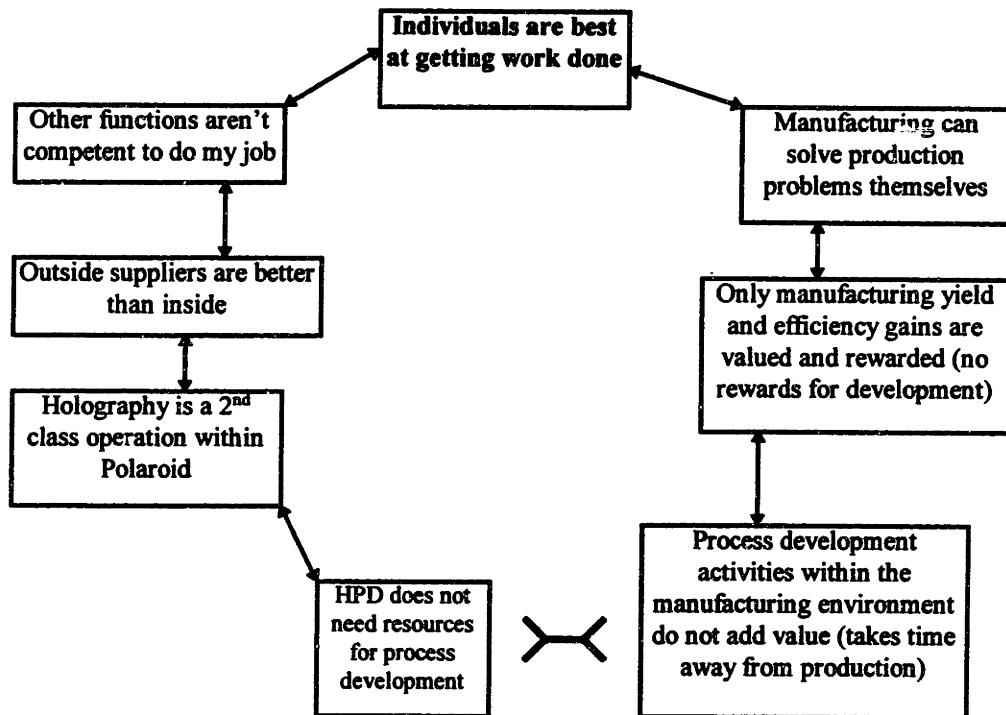


Figure 5.1: Polaroid's Holography Products Division Cultural Paradigm

The main problem I see in holography is that process development activities within the manufacturing environment are not valued. At the same time, very little effort is put into developing the pilot facilities and a working process model to support development activities because of the assumption that holography is a second-class operation within Polaroid. The core assumption discovered through this analysis is that "individuals are the best at getting work done." This assumption seems to support a dichotomy, of other assumptions which at the extreme, are very conflicting. The crisis orientation of HPD at this time accentuates the conflicting assumptions, "process development activities in the manufacturing environment

do not add value,” and “HPD does not need first-rate resources for process development (because it is viewed as a second-class operation).”

5.3 Major Barriers to Change

Early in Polaroid’s history Edwin Land stated the importance of “genuinely new and useful products” that “assure financial success,” and established Polaroid’s focus on neat technology that would sell itself. By giving every employee the “personal opportunity ... for the full exercise of his talents,” Land also initiated a cultural assumption that promotes individualism. HPD’s experience has led to another assumption that “other functions aren’t competent to do my job.” A hierarchical environment where all individuals were allowed to exercise their talents, but where only the experts were competent to do the job, resulted in dependence on the genius of the organization’s leaders.

According to Schein, “What must be avoided in the learning culture is the automatic assumption that wisdom and truth reside in any one source or method.”²⁶ Holography’s first barrier to change in becoming a learning organization is its moralistic belief in the nature of reality and truth. To develop a learning culture, HPD needs to take a more pragmatic approach to problem solving. One example of its resistance to the pragmatic approach was seen when I presented a statistical process control methodology – a purely empirical approach – as a solution to a process problem and received a negative reaction. The HPD organization insisted a new technology was needed to solve this particular problem.

There are other barriers to change that need to be addressed as well. The HPD organization focuses too much on the problematic environment facing them rather than the organization’s approach to solving the problem. Because of this focus on the environment, the nature of activity is too reactive and task oriented rather than being proactive and creating the environment and relationships that are truly desired. Finally, the level of communication is

²⁶ Schein, E.H., Organizational Culture and Leadership (Jossey-Bass Inc., Publishers, San Francisco, CA, 1992).

very low; this may be due, in part, to the turbulence of the corporate reorganization, but the informal nature of communication leaves large gaps that require more individual perseverance and hinder organizational learning.

HPD is trying to serve a new set of customers with higher quality demands. In order to meet these demands quickly there needs to be development of the current process technology. Because of the complexity of this technology and the constrained resources due to the reorganization, the individuals and functions of HPD need to work together in order to share their knowledge and accelerate the learning process. Table 5.1 shows a comparison of the characteristics of a learning culture and my evaluation of the HPD culture. In order to transform the culture into one that facilitates learning, HPD leaders need to understand the organization's current mental models and assumptions and then promote the kind of assumptions and reward behavior that are characteristic of a learning culture.

Table 5.1: Comparison of characteristics for a learning culture (X) versus holography's culture (hpd)

Organization-Environment Relationship		
Environment Dominant hpd →	Symbiotic	Organization Dominant X
Nature of Human Activity		
Reactive, fatalistic hpd →	Harmonizing	Proactive X
Nature of Reality and Truth		
Moralistic authoritative hpd →		Pragmatic X
Nature of Human Nature		
Humans basically evil		Humans basically good hpd → X
Human nature fixed		Human nature mutable hpd → X
Nature of Human Relationships		
Groupism	X	← hpd Individualism
Authoritative/paternalistic hpd →	X	Collegial/participative
Nature of Time		
Past oriented hpd →	Present oriented	Near-future oriented X
Short time units	Medium time units X	Long time units ← hpd
Information and Communication		
Low level of Connectivity hpd →		Fully connected X
Subcultural Uniformity Versus Diversity		
High uniformity	hpd →	High diversity X
Task Versus Relationship Orientation		
Primarily task oriented hpd →	Task & relationship oriented X	Primarily relationship oriented
Linear Versus Systemic Field Logic		
Linear thinking hpd →		Systemic thinking X

Note: Adapted from Organizational Culture and Leadership (p. 365) by E. Schein, 1992. San Francisco: Jossey-Bass.
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5.4 Summary

Through this analysis, I discovered just a small subset of basic assumptions that make up HPD's organizational culture. The core assumption of this subset appears to be rooted in the Polaroid corporate culture. Other assumptions supported by the core assumptions are derived from the specific experiences of the HPD organization, both as a division of a large corporation and as an individual organization. This subset of assumptions may have been very effective in the past for driving product innovation in a budding technology under the corporate umbrella with many resources, but things are changing. The drastic changes that HPD is experiencing are coming from the markets it competes in and the corporation that has fostered it. Because of these drastic changes, HPD needs to adapt its organizational structure and set of cultural assumptions to foster team learning orientations that support process development activities.

The HPD organization is reacting to its manufacturing problems rather than interacting and generating new manufacturing capabilities. Learning is more corrective than transformative. The HPD organization needs to learn how to transform its manufacturing capabilities to its desired state. My initial efforts with HPD were not supported because of constrained resources and conflicts with the organization's cultural assumptions and operational mental models. These assumptions and mental models are the building blocks upon which a culture is defined and they can be the foundations for developing a learning organization.

Chapter 6

6. Developing Organizational Learning Capabilities

The increased complexity and accelerating dynamics of today's marketplace requires a firm to learn more, more quickly, in order to maintain its position. Today's innovations are only realized through the integration of diverse component technologies and when they can be reproduced at a meaningful scale, at marketable cost. Through organizational learning, companies can become more competitive and innovative. In The Fifth Discipline, Peter Senge defines learning organizations as:

"...organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together."²⁷

To be successful, the leaders of learning organizations need to be in tune with the organizational culture. Edgar Schein's research shows that organizational culture can limit an organization's capacity to perceive and understand a new vision, when that culture is primarily the result of prior success.²⁸ The starting point for improving an organization's effectiveness lies in deciphering the organizational culture and then identifying the capabilities that need to be developed to support organizational learning and a systematic view in strategic planning.

²⁷ Senge, P.M., The Fifth Discipline: The Art & Practice of the Learning Organization (Currency Doubleday, New York, NY, 1990).

²⁸ see E.H. Schein, Organizational Culture and Leadership (Jossey-Bass Inc., Publishers, San Francisco, CA, 1992); E.H. Schein, "How Can Organizations Learn Faster? The Challenge of Entering the Green Room," *Sloan Management Review*, Fall 1993, pp. 85-92; and E.H. Schein, "Three Cultures of Management: The Key to Organizational Learning," *Sloan Management Review*, Fall 1996, pp. 9-20.

6.1 Creating a Culture to Support Organizational Learning

6.1.1 The Fundamentals of Building Learning Organizations

Research on organizational learning has been growing for more than 20 years. Argyris and Schon developed some of the first building blocks for understanding how organizations learn with their single-loop and double-loop models²⁹ – these models are also referred to as adaptive and generative learning cycles. Senge has taken the general awareness of organizational learning to a higher level. In The Fifth Discipline, he describes the five disciplines individuals and organizations need to learn in order to function as a learning organization:

- **SYSTEMS THINKING** uses a large body of methods, tools, and principles to focus on underlying trends and interrelated forces of change in business, manufacturing, and organizational processes.
- **PERSONAL MASTERY** allows an individual to break free from the reactive mindset that someone or something else is creating that individual's reality.
- **MENTAL MODELS** are deeply ingrained assumptions, generalizations, or pictures and images that influence how we understand the world and how we take action. An example of mental models that lead to successful learning organizations: Shell's success managing through dramatic changes of '70s and '80s - "think of planning as learning and corporate planning as institutional learning."³⁰
- **BUILDING SHARED VISION** is important for fostering individual commitment rather than compliance.
- **TEAM LEARNING** starts with a culture that encourages dialogue.

²⁹ Argyris, C. and D.A. Schon, Organizational Learning: A Theory of Action Perspective (Addison-Wesley, Reading, MA, 1978).

³⁰ de Geus, A.P., "Planning as Learning," *Harvard Business Review*, March-April 1988, pp. 70-74.

Senge's thrust is that companies need to be better learning organizations to break the cycle of solving systemic problems by implementing symptom-focused solutions that only lead to the need for still more symptomatic interventions.

Managers will want to know what organizational learning does for profitability. Argyris argues that, "the bottom line is not enough criterion to evaluate the importance of generative, organizational learning." Senge's argument is, "While accounting is good for 'keeping score,' we have never approached the subtler tasks of building organizations, of enhancing their capabilities for innovation and creativity, of crafting strategy and designing policy and structure through assimilating new disciplines. Perhaps this is why, all too often, great organizations are fleeting, enjoying their moment in the sun, then passing quietly back to the ranks of the mediocre."³¹

6.1.2 *The Practices of Learning Organizations*

There is a large body of research on organizational learning. Garvin brings together all the definitions used for learning organizations [see Figure 6.1] and reviews the details of practicing organizational learning [see Table 6.1].³² Out of the confusion he tries to provide the *meaning* of organizational learning, *management* guidelines for practice, and *measurements* for assessing the level of organizational learning.

³¹ P. Senge, "The Leader's New Work: Building Learning Organizations," *Sloan Management Review*, Fall 1990, pp. 7-23.

³² Garvin, D.A., "Building a Learning Organization," *Harvard Business Review*, July-August 1993, pp. 78-91.

Some Definitions of Organizational Learning

“Organizational learning means the process of improving actions through better knowledge and understanding.” C. Marlene Fiol and Marjorie A. Lyles, “Organizational Learning,” *Academy of Management Review*, October 1985.

“An entity learns if, through its processing of information, the range of its potential behavior is changed.” George Huber, “Organizational Learning: The Contributing Processes and Literatures,” *Organization Science*, February 1991.

“Organizations are seen as learning by encoding inferences from history into routines that guide behavior.” Barbera Levitt and James G. March, “Organizational Learning,” *American Review of Sociology*, Vol. 14, 1988.

“Organizational learning is a process of detecting and correcting error.” Chris Argyris, “Double Loop Learning in Organizations,” *Harvard Business Review*, September-October 1977.

“Organizational learning occurs through shared insights, knowledge, and mental models ... [and] builds on past knowledge and experience – that is on memory.” Ray Stata, “Organizational Learning - The Key to Management Innovation,” *Sloan Management Review*, Spring 1989.

Figure 6.1: Proposed Definitions of Organizational Learning

Garvin’s working definition of a learning organization is:

“A learning organization is an organization skilled in creating, acquiring, and transferring knowledge, and at modifying its behavior to reflect new knowledge and insights. Without accompanying changes in the way that works gets done, only the potential for improvement exists.”

Members of learning organizations develop a distinctive mind-set, skill set, and behavior pattern. Most managers believe “if you can’t measure it, you can’t manage it.” Organizational learning can be measured through three overlapping knowledge stages: cognitive, behavioral, and performance improvement. A complete learning audit is needed to measure progress in developing organizational learning capabilities.

Table 6.1: Practices of Learning Organizations

PRACTICES	Definition And Required Orientation/Tools
SYSTEMATIC PROBLEM SOLVING	A “fact-based management” approach using statistical tools. Requires a disciplined and detail oriented mind-set. Without this mind-set, managers remain a prisoner of “gut facts” and sloppy reasoning.
EXPERIMENTATION	Motivated by opportunity to build capabilities, not just to eliminate current difficulties. The skills required are statistical methods (like Taguchi methods for design of experiments), graphical techniques, and creativity techniques.
LEARNING FROM THE PAST	A mind-set that, “enables companies to recognize the value of productive failure as contrasted with unproductive success.”
BENCHMARKING	A way to learn from others.
TRANSFERRING KNOWLEDGE	Can occurs through a variety of mechanisms including: written, oral, and visual reports, site visits and tours, personnel rotation programs, education and training programs, and standardization programs. Knowledge is more likely to be transferred effectively when the right incentives are in place; employees need to know that learning will be applied.

To initiate organizational learning, managers need to foster an environment that is conducive to learning, which includes: time for reflection and analysis, strategic planning, dissecting customer needs, assessing current work systems, and inventing new products. Training in brainstorming, problem solving, evaluating experiments, and other core learning skills is essential.³³ Nonaka’s research of innovative Japanese companies suggests that companies use metaphors and organizational redundancy to focus thinking, encourage dialogue, and access tacit knowledge.³⁴

³³ Ibid.

³⁴ Nonaka, I, “The Knowledge-Creating Company,” *Harvard Business Review*, November-December 1991, pp. 96-104.

Learning conforms to culture. In creating a learning mind-set or orientation it is important to gain full knowledge and appreciation of your organizational assumptions about learning to determine where to build on and where to alter existing assumptions. Using the cultural analysis presented in Chapter 4, a strategy can be developed for the HPD organization to develop organizational learning capabilities. Completing a process characterization demonstrates the power of “knowing why” and can serve as an example of organizational learning. By participating on and facilitating a team with the goal of developing organizational learning capabilities, ideas of different organizational constructs can be developed and tested to find one that best fits Polaroid’s organizational culture and promotes organizational learning.

6.1.3 *Vision Statement*

Through working with HPD, I developed the following vision statement for a learning organization:

In a resource-constrained environment, manufacturing capabilities need to be developed through an organization that combines generative and adaptive learning processes to develop the knowledge base required for meeting cost reduction and product quality goals in a timely and efficient manner.

6.1.4 *Organizational Objectives*

The organization described above has the following objectives:

- to increase the level of process knowledge,
- to identify new organizational constructs that will increase the speed and quality of learning, and
- to understand the cultural assumptions of the informal organization that aid and hinder organizational learning; mold assumptions where needed.

6.2 Strategy for Developing Organizational Learning Capabilities

Nevis, et al, at the MIT Organizational Learning Center, have developed a two-part model of organizations as learning systems.³⁵ This model uses seven learning orientations and 10 facilitating factors to define an organization's learning capabilities. The learning orientations are derived from the organizational culture and the facilitating factors are determined by the structure of the formal organization. This model of organizational learning systems assumes there are three-stages to the learning process:

1. knowledge acquisition - development of skills, insights, and relationships,
2. knowledge sharing - dissemination, and
3. knowledge utilization - integration of learning so it is broadly available and generally applicable to new situations.

To formulate a strategy for HPD to develop organizational learning capabilities, I considered the following learning orientations and facilitating factors:³⁶

- **LEARNING ORIENTATIONS** are the values and practices that reflect where learning takes place and the nature of what is learned.
 1. **Knowledge Source:** To what extent does the organization develop new knowledge internally or seek inspiration in external ideas?
 2. **Product-Process Focus:** Does the organization prefer to accumulate knowledge about the product and service outcomes or about the basic processes underlying various products?
 3. **Documentation Mode:** Do attitudes vary as to what constitutes knowledge and where knowledge resides?
 4. **Dissemination Mode:** Has the organization established an atmosphere in which learning evolves or in which a more structured and controlled approach induces learning?

³⁵ Nevis, E.C., A.J. DiBella, and J.M. Gould, "Understanding Organizations as Learning Systems," *Sloan Management Review*, pp73 - 85, Winter 1995.

³⁶ Ibid.

5. **Learning Focus:** Is learning concentrated on methods and tools to improve what is already being done or on testing the assumptions underlying what is being done?
 6. **Value Chain Focus:** Which core competencies and learning investments does the organization value and support?
 7. **Skill Development Focus:** Does the organization develop both individual and group skills?
- **FACILITATING FACTORS** are the structures and processes that affect how easy or hard it is for learning to occur and the amount of effective learning that takes place.
 1. **Scanning Imperative:** Does the organization understand or comprehend the environment on which it functions?
 2. **Performance Gaps:** How do managers analyze variances between targeted outcomes and actual performance? Is there a potential new vision that is not simply a quantitative extension of the old or goes well beyond the performance level seen as achievable in the old vision?
 3. **Concern for Measurement:** Does the organization develop and use metrics that support learning?
 4. **Experimental Mind-Set:** Does the organization emphasize experimentation on an ongoing basis?
 5. **Climate of Openness:** Are the boundaries around information flow permeable so people can make their own observations?
 6. **Continuous Education:** Is there a commitment to lifelong education at all levels of the organization?
 7. **Operational Variety:** Is there more than one way to accomplish work goals?
 8. **Multiple Advocates:** Along with involved leadership, is there more than one “champion” who sets the stage for learning?
 9. **Involved Leadership:** Is leadership at every organizational level engaged in hands-on implementation of the vision?
 10. **Systems Perspective:** Do the key actors think broadly about the interdependency of organizational operational variables?

Nevis suggests that organizations can enhance their learning capabilities in three ways: change learning orientations, embrace the existing style and improve its effectiveness (improve a few facilitating factors), and change some learning orientations and facilitating factors at the same time. Changing the learning orientations is useful if the current learning orientations have provided the organization with strong capabilities and if a desired change in strategic position

requires new learning capabilities. Improving just facilitating factors may be needed when improving the systems and structures of the organization will enhance learning capabilities, but the current learning orientations are appropriate for the culture and business. Changing both learning orientations and facilitating factors is required when large-scale change is necessary.

There are two alternatives for improving organizational learning capabilities that I recommend for HPD to choose from:

1. Improve on learning orientations:
 - Process Focus: By taking more of a process focus, technological product innovation will be complemented with the manufacturing capability needed to be commercially successful.
 - Team Skill Development: Providing all levels of the organization with the ability for skillful dialogue will make tacit process knowledge explicit organizational knowledge. Much of the current process knowledge is tacit - in the operators' heads. In HPD, the operators went about their normal daily routines letting the "process experts" solve the manufacturing problems - all the while trying to stay out of the operators' way. By providing the problem solving, experimentation, evaluation and dialogue skills to all members of the organization, operational capabilities will improve rapidly.
 - Documentation Mode: A formal experimentation reporting structure needs to be instituted. The special task force for process improvement tried to initiate a documented test request, but it was dropped as soon as the task force disbanded. Regularly scheduled progress reports should be required. Some bureaucracy is necessary.

- Dissemination Mode: Bringing the whole organization together occasionally to discuss experimental results or successful problem-solving activities will greatly expand the organizational knowledge and encourage a shared vision (or team spirit). On a larger scale, Polaroid should have annual symposia to bring together the various divisions that are scattered geographically and share important findings.

Before changing these learning orientations the whole organization should understand its culture and believe there needs to be change. Remember learning conforms to culture, so suggesting that learning orientations must change is saying that the culture must change, and people may take this as a personal attack.

2. Improve both learning orientations and facilitating factors:

- Scanning Imperative: A system that encourages benchmarking and studies the practices of competitors and other well-performing companies can be very instructive in building one's own capabilities.
- Operational Variety: An incentive system should be devised to address developmental as well as operational goals. Current resources for development are very slim, but the need for development is pressing.
- Concern for Measurement: By establishing measures for development and learning, and rewarding the organization based on these measures, HPD can enhance its strategic position and demonstrate the value of process development. The Polaroid Corporation has established the economic value added (EVA) measure as a means for rewarding employees based on corporate and divisional financial performance, but what about developmental performance? Polaroid has a wealth of technical

competencies, but the process development capabilities aren't available for successful innovation and commercialization.

- Team Skill Development (see above)
- Documentation Mode (see above)

Changing both learning orientations and facilitating factors can help to achieve the change that HPD and the Polaroid Corporation should be looking for. To implement either of these strategies, HPD might start with changing facilitating factors because these are typically the easiest for an organization to accept. The HPD organization does seem to be in some state of confusion and open to exploring needed cultural changes. Getting buy-in on cultural change would be a stronger approach because the organization will be less likely to disregard new management policies instituted by new managers from outside the organization's history who haven't gained complete trust yet.

6.3 Summary

Remember, learning conforms to culture and transitioning from job-shop to standardized manufacturing requires a lot of learning and, most likely, culture changing. For organizational leaders to be successful they need to be in tune with the organizational culture. The appropriate organizational learning processes and managerial leadership can improve process development capabilities and advance the current manufacturing system to the ideal system for standardized production. This chapter was meant to provide an overview of the fundamentals and practices of learning organizations, and to present the use of a framework for formulating a strategy to develop organizational learning capabilities. Organizational learning can improve management of technical knowledge and enhance process development capabilities.

7. Conclusions and Recommendations

Growing interest in systems thinking reflects a recognition that the individual's ability to understand how the world works is limited. My thesis argues that in a more competitive and complex business environment firms need to utilize the skills of the *whole* organization, to use a system perspective, and to take an interactive approach to process development and problem-solving; this means developing learning organizations. A company's capability for rapid development and implementation of technical knowledge can be a competitive advantage. This research focuses on the organizational culture, the management of technical knowledge, and the organizational learning capabilities that rapidly develop technical knowledge and lead to efficient manufacturing processes.

7.1 Conclusions

The transition from job-shop to standardized manufacturing can be very difficult to manage. These manufacturing systems require two very different sets of process designs, process technologies, operational procedures, organizational structures, and organizational capabilities. All of these factors must be considered when formulating a strategy to make this transition. Process development capability is the key component of a business strategy that encompasses all of the above factors and enables a company to make the transition smoothly. A systematic approach to process development that identifies an idealized manufacturing system is needed to make leaps in manufacturing capability.

Polaroid's Holographic Products Division (HPD) is pursuing a new strategic position and needs new manufacturing capabilities to complement this position. The formal organization has also changed dramatically because of a divisional reorganization, but new organizational structures need to be defined to provide purpose and clarity in direction to the remaining organization; these structures should include facilitating factors for organizational learning.

The organization also needs new learning capabilities if it wants to achieve its strategic position quickly and efficiently.

7.2 Recommendations

Through teamwork with HPD, I was able to diagnose HPD's methods for managing technical knowledge and identify organizational obstacles to improved process development capabilities. By performing a cultural analysis with a product development team, I tailored a strategy for developing organizational learning capabilities for HPD's needs. By enhancing a few learning orientations and facilitating factors for the organization, process development capability can be improved and the business strategy to transition from job-shop to standardized manufacturing can be made more effectively.

HPD should lead the way for the corporation in developing organizational learning capabilities. By understanding its own culture, the organization can identify assumptions that aid or hinder organizational learning and can choose a strategy for developing organizational learning capabilities. There are two alternatives that I recommend for HPD to choose from:

1. **Improve on learning orientations:**
 - **Process Focus:** By taking more of a process focus, technological product innovation will be complemented with the manufacturing capability needed to be commercially successful.
 - **Team Skill Development:** Providing all levels of the organization with the ability for skillful dialogue will make tacit process knowledge explicit organizational knowledge.
 - **Documentation Mode:** A formal experimentation reporting structure needs to be instituted. The special task force for process improvement tried to initiate a documented test request, but it was dropped as soon as the task

force disbanded. Regularly scheduled progress reports should be required, too.

- **Dissemination Mode:** Bringing the whole organization together occasionally to discuss experimental results or successful problem-solving activities will greatly expand the organizational knowledge and encourage a shared vision (or team spirit).

An alternative strategy, if the organization is ready for it, is:

2. Improve both learning orientations and facilitating factors:

- **Operational Variety:** An incentive system should be devised to address developmental as well as operational goals. Current resources for development are very slim, but the need for development is key to HPD's competitive advantage.
- **Concern for Measurement:** By establishing measures for development and learning, and rewarding the organization based on these measures, HPD can enhance its strategic position and demonstrate the value of process development. The Polaroid Corporation has established the economic value added (EVA) measure as a means for rewarding employees based on corporate and divisional financial performance, but what about developmental performance? Polaroid has a wealth of technical competencies, but the process development capabilities aren't available for successful innovation and commercialization.
- **Team Skill Development:** Much of the current process knowledge is tacit – in the operators' heads. In HPD, the operators went about their normal daily routines letting the “process experts” solve the manufacturing problems – all the while trying to stay out of the operators' way. By

providing the problem solving, experimentation, evaluation and dialogue skills to all members of the organization, operational capabilities will improve rapidly.

- Documentation Mode: A formal experimentation reporting structure needs to be instituted. Regularly scheduled progress reports should be required.

7.3 Directions for Future Research

My internship was a very good learning experience, but the dynamic organizational environment made it difficult for me to research some issues in more depth, such as:

- Process characterization for chemical processing of holograms; I truly believe that pursuing this activity will both enhance HPD's operational capabilities and provide an example, or pilot test, of the organizational learning concepts I presented.
- Interactive planning and the "idealized design" approach to comprehensive strategy formulation; Many managers look at their Management by Objective (MBO) goals and then determine what business strategy to pursue without considering the capabilities of the organization and the set of capabilities needed for the business strategy to be successful. Through interactive planning, is a manager more likely to consider the capabilities issue and arrive at a more comprehensive and implementable strategy?
- Design of organizational incentive systems to reward development performance; Incentive systems aren't the answer to all managerial problems, but they are important. I think the latest financial performance measures and stock incentive plans are innovative approaches to incentive system design, but they are lopsided. For technology based companies who rely on product and process innovation, there need to be better performance measures for development activities.

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8. Appendix A

Memo

Summary

In the middle of August there was some frustration concerning the quality and the useful-life expectations for the tools used on HP-1. At that point a new inspection procedure was being implemented to qualitatively determine the expected product yield from a given tool, but this inspection did not indicate the tool durability. To address this issue, a database of tool characteristics has been developed for analysis to determine what the process control limits are for tool manufacturing. The analysis indicates that the current tool manufacturing process produces tools with a normalized standard deviation of 0.33. From the data available, the average useful tool life was calculated as 950 meters.³⁷ Tools manufactured within a 3 sigma range of the mean have an average useful life of 1070 meters. Outside of this 3 sigma range the process appears to be out of control resulting in tools with an average useful life of 250 meters. Approximately 15 percent of the tools produced are outside this 3 sigma range. If these tools are identified and scrapped before the final tool finishing step, a savings of 20 percent can be realized and the average useful life of a tool will increase by 100 meters.

A Key Measure for Determining Tool Quality

Analysis of available data from the past five months indicates that the tool manufacturing process results in 33 percent standard deviation for a key characteristic. Figure 1 is a historical chart of the key tool characteristic with the mean and 3 sigma limits indicated. There appears to be a step drop in this characteristic after early July; this is most likely due to a change in the requested specification requested from the finishing vendor and increased scrutiny of tool quality. Figure 1 shows the high variability in the tool manufacturing process.

³⁷ Tool life is measured in meters because that is the amount of holographic film the tool is exposed to before the product quality degrades to such a level that the manufacturing supervisor decides to replace the tool.

Some of the tools that had been measured for the key characteristic were used on HP-1. Figure 2 shows the average useful life for tools of a given characteristic. The bars associated with each data point are 70 percent confidence intervals (based on the Student's t-distribution because of a small sample size) around the average. For example, a tool with a coat thickness of 0.0065 inches can be expected to have a useful life of 280 to 1420 meters with 70 percent confidence. The 70 percent confidence interval was chosen because it provided positive lower-limit life expectancies for all characteristic values considered.

Discussion of Results

A tool can be scrapped for many reasons. The reasons a tool may be scrapped are not all related to characteristics specific to the tool. There are more than three reasons for scrapping tools that are the result of interaction between the tool and the machine (HP-1); these reasons are not solely related to the characteristic of the tool itself. There are only a couple of reasons for scrapping tools that are solely related to the tools. Because it is very hard to detect the causes solely related to the tool and it is hard to distinguish the causes related to the tool-machine interaction, the analysis presented here treats all the data equally. Analysis of the data in Figure 2 indicates that tools outside the 3 sigma range perform consistently worse than tools produced within the 3 sigma range, regardless of the reason for scrapping the tool. This result may indicate that tools outside the 3 sigma range may have been produced by a process that is "out of control."

Possible reasons for a final characteristic outside the 3 sigma range are: the quality of raw material, the consistency in processing parameters, the quality of processing, or too much final finishing. On the low side of the 3 sigma range, the tool life is probably shortened because of the quality of the tool itself. On the high side of the 3 sigma range, the tool life may be shortened because of undesired interaction with machine.

Cost Analysis

Table 1 is a cost analysis for tool production needed to fill an order of 1 million Imagix® Eagle Images. This cost analysis considers two scenarios: 1.) all tools are finished, and 2.) only

tools within 3 sigma limits get finished. This analysis uses the average tool lives reported above and assumes the following:

- current yield of tool process is 60 percent,
- scrapping tools outside the 3 sigma limit increases the yield to 70 percent,
- the cost of finishing is \$400, an average of four tools are shipped on each round trip, and shipping costs are \$180 per trip. Under these assumptions, if all tools are sent for finishing, a total of 53 tools must be manufactured at a total cost of \$23,500. If only tools within the 3 sigma limits are diamond turned, 40 tools would be required at a total cost of \$18,000.

Recommendations

- Implement an inspection before tool finishing,
- Finish only the tools that are found to be within the process control limits (3 sigma range), and
- Investigate methods for measuring key characteristics consistently.

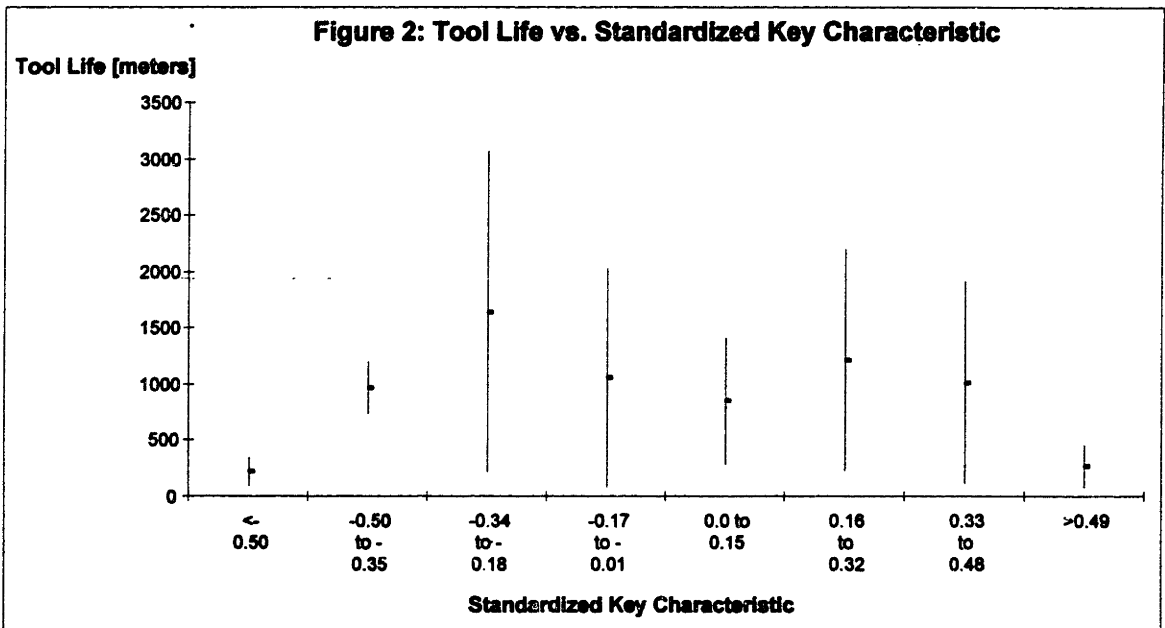
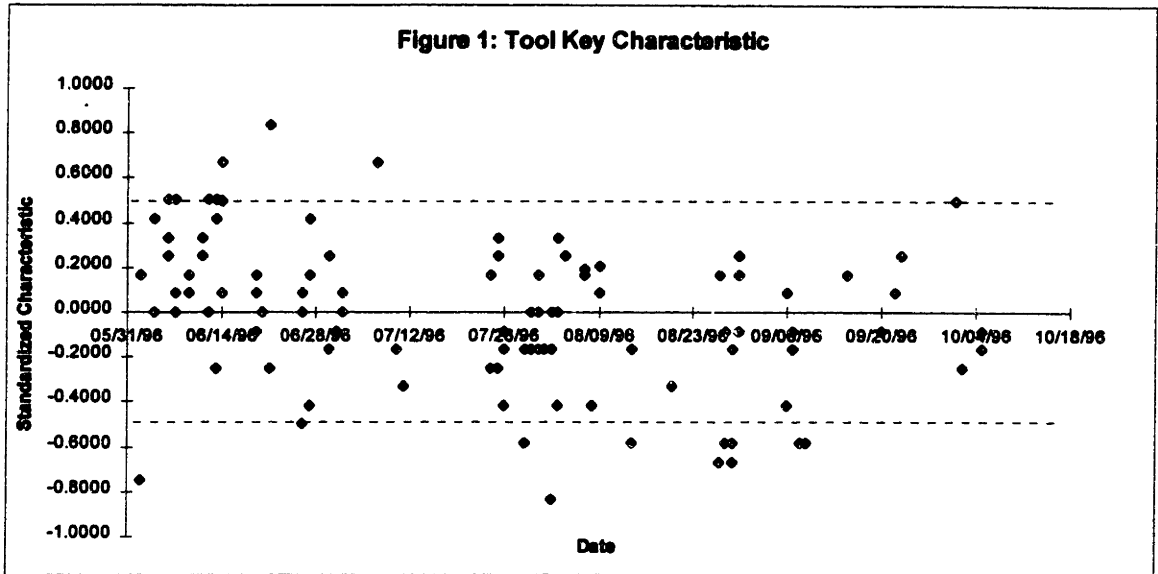


Table 1: Tool Cost Analysis for Producing 1,000,000 Imagix^(R) Images

	<u>Use All</u>	<u>Scrap if key char. > 3σ limits</u>
LM TO HP1	30125	30125
/ TOOL LIFE IN LM	950	1070
/ TOOL YIELD	60%	70%
NO. TOOL FINISHED	53	40
* FINISHING COST/TOOL	\$ 300	\$ 300
* SETUP COST	\$ 100	\$ 100
FINISHING COST TOTAL	\$ 21,140	\$ 16,088
NO. TOOLS FINISHED	53	40
/ TOOLS PER TRIP	4	4
* COST/ROUND TRIP	\$ 180	\$ 180
TOOL TRANSPORTATION COST TOTAL	\$ 2,378	\$ 1,810
TOTAL TOOL COST	\$ 23,519	\$ 17,898
SAVINGS		24%

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