Systems Integration for Digital Textile Printing

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Abstract

Systems integration (SI) has revolutionized and improved the way we use computers and conduct business. Companies are increasingly employing systems integration methodologies and approaches to design products, services and technology. This paper notes the trend away from conventional systems development and details systems integration approaches for designing digital textile printing processes. The experience, methods and practice of computer systems integration suggest models for guiding digital textile printing technology development toward market acceptance. The development experience of existing digital textile printing devices provides additional useful models. This paper reviews the development models of four digital equipment companies, Canon, Seiren, Stork, and Toxot and evaluates their ability to meet market requirements and changing demand. Drawing on the successful aspects of these models, the author suggests issues to consider in designing a model for integrating digital textile printing systems. It considers technological developments and market forces which are driving the adoption of digital technology for textiles.

Methodology

The author has collected the information for this report from interviews with first hand observers and developers. He has also surveyed available literature and published economic data.

Introduction

Systems Integration is a rapidly growing discipline governing the design and implementation of business and computer systems. It brings together diverse parts to create an operationally harmonious whole or successful solution. Over the past 15 years since the advent of microcomputers, computer systems design has shifted from database and application centered systems development to interface centered systems integration. As computer use expanded from specialized professionals to include the general populous, computer systems designs changed to meet the needs of the new and more numerous users. People demanded computers they could learn to use quickly and intuitively, with consistent commands from one application to others. They wanted their applications to easily be able to communicate and share data without corrupting it. These wishes resulted in almost universal adoption of Graphic User Interfaces (GUIs) with translation capabilities. As these microcomputer users demanded the ability to communicate and share data with others within and outside their organizations, the role and importance of systems integration increased. As one indication of its impact, GUIs consume approximately 80% of all central processing unit (CPU) cycles on the average desktop computer.

The initial development of digital printing followed more conventional systems development focusing on proprietary systems and applications. The Milliken Millitron and LaserMaster ink jet devices printed limited substrata using proprietary software and consumables.

More recently, digital printing equipment developers have generally adopted GUIs for their ease of use, multi-tasking and graphic functionality. Many, however, still attempt to control supply of consumables used in their devices by limiting their equipment warranties and support to those using their authorized inks, toners and media. Most digital printing technologies operate within very narrow and demanding tolerances. They usually require the close coordination of chemistry, printing equipment, software and media to achieve optimum results. Few companies are capable of or interested in developing all of these technologies on their own. Partnering relationships and alliances have evolved among companies developing the various elements of the digital printing. Usually, one company acts as systems integrator. A level of communication, information exchange and cooperation are necessary between all of the participants for the greatest level of system integration and success.

The satisfaction of end user intentions determines operational success. For most market segments, one can anticipate end user intentions based on current market demands and projecting trends. Some system integrators set meeting corporate strategic goals as the measure of success. Since corporations, however, usually place customer satisfaction at the core of their mission statements, this report assumes a congruence of corporate mission and strategic goals with customer satisfaction. Market acceptance, after all, is the generally accepted and measurable standard of success.

Systems integration is one of the most rapidly growing business service categories because its systems professionals help companies keep pace with technological and business change. Systems integrators include large and profitable companies such as, American Management Systems, Andersen Consulting, BDM Technologies, EDS, Ernst and Young, and Perot Systems. These specialize in integrating people, computers, databases, software applications, networks to perform business tasks quicker and more effectively than with less integrated systems. The continued growth of systems integration attests to its success in satisfying its customers and attracting new ones.

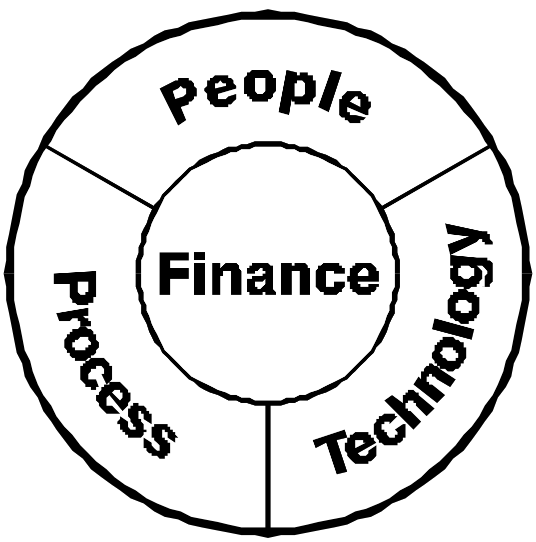

Fig. 1: The Elements of Systems Integration

The Elements of Systems Integration

System integrators encompass people, process, and technology as an integrated system's essential elements. This author adds financial resources to this triumvirate of elements. System integration blends humans, their abilities and preferences with business processes and technology to accomplish goals and facilitate customer intentions.

People are the human factor, the makers, suppliers, users and customers. They are the most important element, the starting and ending points for system integration. People give systems meaning and purpose. Customers and users have to want a system or the benefits it produces for it to have any value. The creation of a digital textile printing system will involve a dynamic social community of people performing financing, marketing, accounting, purchasing, negotiating, contracting, engineering, programming, designing, assembling, and managing functions. An integrated system meets the needs and expectations of the different types of people that have a stake in it.

SI focuses on the interfaces of people with both business procedures and technology. The "people element" involves psychology, sociology, ergonomics, business politics, education and graphic design. Systems integrators must account for the human work habits, preferences, differences in the learning styles and limitations. Systems integration like ergonomics fits tools to the users rather than trying to adapt users to tools.

Specific people focused activities of computer systems integration include the design of both the hardware and software human-computer interfaces, integration of application and multimedia components into it, and customer training support during and following system implementation.

SI addresses the People element when it answers how each participant benefits to their satisfaction. Systems operate most effectively when the needs of all participants are addressed. Nature affords numerous examples of the efficacy of this principle. For instance, Hunger is a body's way of telling other parts of the system to supply food. Systems require communication between its parts and through a central control integrator. Organizations of people have the same needs if they are to accomplish their missions or common goals. An organization which comes together to develop a product, such as a digital textile printing system, must necessarily involve and address the needs of all participants from end users to raw material suppliers in order for the system to succeed. A more accurate definition of a system's success would involve the satisfaction of all parts of the system as well as the customer.

SI also considers organizational politics and the people factors of more traditional project management. Organizations operate with different corporate philosophies and cultures. Particularly when integrating different organizations, SI must account for these factors.

SI pays particular attention to the need for training and education of the people within the system. This is particularly the case for the successful operation of digital systems, which require precise directions to perform. Unless suppliers, manufacturers, marketers, print producers and end users know how to play their roles competently, it is not unlikely that they will not. The development of an effective training program results of a trial and error, on-going feed back and continual improvement process. As an organization prepares for production printing, its users will have had to achieve the necessary operational precision.

The motivation, inspiration and skill which produces the artist output of textile design drives the integrated digital printing system. The engendering of these requires dependency on graduates of long term courses of study and endeavor.

Processes refer to business and manufacturing procedures necessary to accomplishment work, tasks, services and product manufacture. Organizations have rou-tines, standard operation procedures, production schedules, accounting protocols, marketing mechanisms. Successful integration of digital textile printing systems require procedures to supply, operate, maintain, and monitor them.

Marketing processes such as market surveys and analysis should help developers create systems which are responsive to market demands and conditions. A printing company, such as Seiren has a distinctive advantage in this regard for developing new printing equipment systems due to its understanding and closeness to customers for printed textiles.

Technology is knowledge applied, the tools which do the work. For digital textile printing, it encompasses software, hardware, chemistry, and media.

The list of technology integration issues includes systems architecture, inter- or multiplatform capability, graphic user interface operating systems, and application development languages. For information systems, technology is centered around its architecture, or the structure of its systems software and hardware. Systems architecture has become much more open and flexible. Usually based on widely adopted standards which many developers have embraced, these standards enable various applications from a variety of vendors to communicate and work together seamlessly. In the past, Macintosh systems have predominated in the design market. On the other hand, higher-end systems were often Unix based. This was particularly the case with textile design. Windows and NT graphics design users are now growing in number and as a share of the graphic arts market. NT and Unix are particularly relevant as the leading platform server operating systems at the center of may integrated information systems. In such a multiplatform design world, inter-platform capabilities have become necessary for true systems integration. Since the graphic arts and textile design industries involves many organizations of customers, designers, suppliers, manufacturers and printers operating a variety of disparate platforms and applications, the importance of transparent data exchange while maintaining security become critical.

Other technical areas of concern for systems integrators include databases, internal and external networks, the internet, enterprise document management (EDM), electronic data interchange (EDI), security, authentication and privacy. System integrators tailor systems, such as digital textile printing systems, with relevant components. Total integration of all organizational systems can prove burdensome, unworkable and counterproductive. In many organi-zations, computer controlled printing systems would operate as stand alone systems, while at others, the printing system would serve as part of an integrated business system.

Modems, the Worldwide Web and internet are rapidly changing database management. Printers, designers and clients are now communicating complex graphic design data, information and instructions by direct telephone and internet channels. Libraries of designs and archives of images are also available likewise. The compactness and flexibility of magnetic and optical computer storage media are relieving printers of much of their archiving burden. Conventional database management systems (DBMS) provide controls which maintain data integrity and availability. Today, SI is blending the strong points of the Web and DBMS.

Networks supply the communications channels which carry data and information. The internet and data telephone lines are quickly becoming the way businesses communicate with their clients and vendors. The software and standards which are evolving to communicate on the internet also can and will form the basis for internal business applications.

The technology of SI also includes the hardware which runs the software. For the purposes of integrating systems, one must match the hardware's requirements and processing capacities with available resources and production demands. Integrating digital printing systems involves other technological disciplines as well, such as ink and toner chemistry, digital printing physics and engineering.

Financial Resources refers to money which employs the people, sustains the business processes and designs, manufactures, purchases and maintains the technology. Many well designed systems founder for lack of funding. Substantial financial backing enable the development of successful digital printing systems. Some integrators subsume this essential element under budgets in the Processes general category. This author believes its essential importance calls for its recognition as a separate element.

In summary, SI has grown to an area of study with the user demand that computers, software and peripherals work together. It derives from business and industrial systems development, but differs in addressing not only engineered design factors, but also the relationships of the parts. While conventional systems development focuses on the technical components, system integration emphasizes where and how they meet, or interface. Conventional systems development begins with the parts then devises ways to connect them, while system integration begins with the relationship of the elements, including the people, and then designs the parts to create the successful relationship. System integration pays particular attention to the people: vendors, developers, workers, customers and end users. As an example of the success of system integration, graphic user interfaces

(GUI) have become the rule because customers generally prefer them over their user unfriendly alternative. Currently, software advances follow and are largely dependent on interface advances. Interfaces provide the operational forms which carry the application functions. They impose functional consistency between applications which results in a shortening of the time necessary to train users. Interface software also permits component application programs to seamlessly communicate, exchange data and work together.

Systems Integration Limitations

System integration offers a theoretical base which can tie operations together to achieve organizational objectives. Often companies contract systems integrators from outside of their organization to integrate their systems. These integrators will have difficulty discovering the real corporate culture and political dynamic underlying a company's image. Systems integrators can often provide clear visions of the road ahead and systems designs for reaching destinations, but the company served must drive down that road and implement the integration.

The users of integrated systems expect easy to use tools which produce quick and effective results. Often the marketing for a product or service will create expectations beyond its capacity to satisfy. Learning how to use any system requires training. Companies need to invest in teaching their staff users how to use their systems to be most effectively. Training is essential for successful operation of digital printing systems. It decreases the period of time necessary to learn to operate a system successfully and profitably. SI does not happen by itself. People, integrators and users, make it happen and they need training or more costly trial and error to learn how to make it happen..

One can have a system which has all of its elements successfully integrated save one. Computer based systems are particularly vulnerable since they can not perform without precise instructions according with their particular logic. One missing element will cause a program and its system to dysfunction and not succeed in achieving its intended goal. Systems containing tens or hundreds of thousands lines of programming code, with print engines printing at tens of thousands of cycles per second, printing mega to gigabits of multicolor graphic information, have to be so well conceived and precisely constructed to obviate the statistical probability of failure.

The Computer Systems Integration Model

The computer systems integration model not only suggests approaches for integrating digital textile printing systems, it controls the brain of their operations. Computer systems integration has evolved from Database Gateways which provide communications channels between the databases of applications, Frontware which adapts mainframe programs, and Application Program Interfaces (API) which connect specific applications, to Graphic User Interfaces with data format translation, information mapping and distribution capabilities. These GUIs can translate the universe of data formats. These have particular relevance to digital printing and the translation of the various graphics and text formats.

The more fully integrated computer information system permits the maintenance of audit trails, application rules and functionality, database integrity, indexing and validation, real-time transaction processing, multiple data source integration, multiple data type and format integration. It also provides ease of learning, no custom coding or maintenance.

The goal of computer systems integration is to increase flexibility, communication and data exchange across platforms and applications so as to improve an organization's ability to achieve its mission and objectives. Information exchange involves the following three steps. The first, Information Analysis, identifies the business goals which integrating systems can accomplish. Computer systems use applications to accomplish tasks. The integrators reduce goals to strategies and strategies to tasks. In this step, one has to determine the information the application requires to perform its tasks, its data requirements and how one will access it. One must also establish the number and location of information supply sources and if the information needs to be bi-directional and return to its source. This step focuses organizational goals and discovers if the necessary data exists and is available. The second step, Connection, addresses the physical connections between applications. These involve input and output devices, printer ports, data files, terminals, middleware queue messages, EDI feeds and APIs. Connections are via networks, modems, cables or transmissions. In the third step, Translation, an integrator application captures, manages and translates incoming information from source format into the target format protocols and communicates it to the target application. This process receives and transmits data in the format of the application addressed. This providing disparate applications with integration into an information system without compromising any of the applications' functions. The integrating translator accomplishes this with economical and reusable executable subroutines which combine to perform any translation.

This three step process is at the technical core of computer system integration. A fully implemented system would involve a complex of disciplines including: Business Process Analysis & Reengineering, Data Management, Network Management, Hardware Management, Software Engineering, and Training. These are also necessary for integrating digital textile printing systems.

The Computer Integration Model and Digital Textile Printing

As peripheral devices, digital textile printing systems are part of the computer systems integration model. Printing devices also have their own complex of parts requiring integration into a system. In addition, textile printing and processing have requirements which also require systematic integration. In effect, textile digital printing extends and expands the computer model to include the elements of textile printing and processing. Added to Business Process Analysis & Reengineering, Data Management, Network Management, Hardware Management, Software Engineering, and Training are Chemistry, Physics, Thermodynamics, Material Handling Engineering, Color Science, Art and Design. This complex of disciplines and the systems within a system they produce, require a significant level of integration to function with any proficiency.

The digital textile design and printing system blend computer aided design (CAD) functions of the designer with computer aided manufacture (CAM) of the printer and textile processor. Textile designers and printers use a variety of formats, some raster and others vector based. The various design platforms, such as Macintosh, PC and Unix based among others, also require integration into the design and printing system. The professional textile print provider has to be able to digitally communicate with all these platforms, and receive, and use graphics and information from all of them in the universe of formats. Intuitive GUIs are providing designers not only with the ease of use they demand, but also the means to translate the universe of formats.

Graphics files are often large and complex. They require fast memory rich platforms for practical use. The higher resolution of a digital printer the greater its needs for storage and processing capacity. The decrease in the cost of processing and storage memory has paralleled the increase in the ability and economic feasibility to digitally print high resolution images. In short, graphics operations require very fast computers with large storage and processing capacities.

Digital textile printing SI applies and extends the computer SI model. The integration of digital textile printing employs such a complexity of disciplines addressing such a wide breath of issues that knitting its parts together is particularly challenging. In the following pages, you will discover how a number of textile printing developers have met this challenge.

Current Digital Textile Models

This report examines how four digital textile developers Canon, Seiren, Stork, and Toxot have integrated the various elements necessary for digital textile printing. Canon has developed printers for both direct and indirect printing. Their office color laser copiers and ink jet printers produce transfers for the novelty garment and accessory textile markets. This paper, however, examines the development model for the Canon Bubble-Jet Textile Printing System. It will also outline Seiren, Stork and Toxot textile printing development models.

The size limitations of this article prevents inclusion of all relevant textile printing systems. The Scitex Iris proofing system is similar to Stork's. Airbrush systems, such as those from Belcom, Vutek and Signtech limit textile printing to canvas and are not included in this discussion. It also does not address indirect transfer textile printing, such as electrostatic, electrophotographic and ink jet transfer, and thermal transfer printing.

Table 1: A Comparison of Textile Printing Systems

	Canon	Seiren	Stork	Toxot
Print Engine	Thermal Ink Jet	Piezo Ink Jet	Hertz Continuous Ink Jet	Multi-level Continuous Ink Jet
Ink System	Dye-based Ink (pigment capable)	Dye-based Ink (pigment capable)	Zeneca Procion Reactive Dye-based Ink	Pigment or Dye-based Ink
Color System	8 color process +	Spot color	4 & 8 color process	4 color process, +
Throughput	1.65 sq. m/min	<.5 sq. m/min	<.1 sq. m/min	.5 to 40 sq. m/min
Max Size	1.65 m. web		1020 X 1850 mm	2 m web
Resolution	360 dpi 180 dpi +	900 dpi apparent	10 pixels/mm	120 or 180 dpi
Price	$900,000	NA	$100,000	$125,000 to $3.5 million
GUI/Integrating Software	Window	Unix	Windows	Windows

Canon

In 1990, Canon partnered with Kanebo, one of Japan's oldest textile manufacturers, to develop a bubble jet digital textile printer. In June 1996, Canon debuted its Bubble Jet Textile Printing System at Vienna, Austria. It represents the first bolt fabric digital short run production machine printing 1.65 meter widths at a rate of 1 linear meter per minute. With this printer, Canon integrates many of the technical elements so as to provide a convincing operating model which points to future development.

Canon supplied the vision, expertise and finance (reportedly over $50 million) to create an impressively integrated system. It developed and integrated continuous web material transport which controls fabric movement during the printing process within exacting parameters. Its image transfer software selects from a theoretical range of 16.7 million colors for color matching. The software runs under the Windows operating system and processing images in Adobe Photoshop TIFF format. In addition to color matching, it offers editing and color replacement functions. One can also adjust colors to compensate for the influence of different fabrics, such as cotton, silk, nylon and polyester. The software directs the 360 dpi bubble jet printing system consisting of an array of 16 print heads with 1,360 nozzles. Canon mounted these traversing heads in two sets of 8 permitting bi-directional extended gamut eight color printing. Each print swath measures 9.6 cm wide. The system can produce 256 gradations for each color. With the Bubble Jet Textile Printer, Canon established the feasibility of short production digital textile printing. This printer demonstrates fabric manipulation and transportation in addition to dye-based digital textile printing.

The system prints 8 color dye-based ink sets. A different dye set is used for each fiber type. Reactive dyes are used for cellulosic cotton, linen and rayon, as well as for protein fiber, silk. Acid dye-based inks for nylon, silk and wool, and disperse dyes for polyesters and other synthetics. Fabrics require a pretreatment coating to prevent bleeding and post treatment of color fixing, washing and drying. At present, the device does not print with pigment-based inks. It reportedly weighs 7 tons and costs about $900,000. It is 3.8 meters wide, 6.4 meters deep, and 1.7 meters high.

Canon continued to refine this device after its initial release. Its development team significantly increased the reliability of its print heads. It extended print head life from 14 hours to a guaranteed 130 hours of operation. It modified its inks to reduce kogation, the burnt residue which builds up on the surfaces of bubble making thermal resistors causing print head failure. It added a head cleaning system to eliminate nozzle clogging due to lint and dust blockage. The resistor, remains a weak point in the process. Besides being hammered with the force of several thousand bubble implosions per second, the heat resistor suffers from normal deterioration which miniaturized heat resistors experience, in addition to kogation. By greatly extending the practical life of its relatively inexpensive print heads, Canon demonstrated both its determination to make its technology viable and its technical capabilities.

The Bubble Jet Textile Printer's one meter per minute production speed should theoretically match the needle time of some garment sewing operations, so that one should be able to keep pace with some garment in-line manufacturing with a cutting head and feed to a modular sewing unit. Agile manufacturing operators will want to expand the functionality of Canon-like textile printers by adding both in-line post processing and fabric cutting. They will also want the ability to print blended fabrics, like cotton-polyester, and use pigment-based in addition to dye-based inks.

Canon integrated a complex of subsystems into digital textile printing system. It marshaled the people, processes, technology and finance to create and launch its textile printer. This project achieved its technical success due to Canon's commitment, investment and considerable expertise. Canon relied on its extensive experience and knowledge of bubble jet technology, digital image processing, ink chemistry, software development and fabric pretreatment. Canon's partnering with Kanebo supplied the fiber and fabric manufacturer perspective. Canon's financing and market position could command the best engineering skills to design and build the Bubble Jet Textile Printer's high precision material transport system. Canon has set the standard for technical systems integration against which the market will measure other digital textile printing systems.

The final measure of success is beyond technical achievement. It's market adoption. Printers and manufacturers want to know the length of time necessary to payback their investment in this device. How can a $900,000 printer operating at a maximum production speed of one running meter per hour be profitable? Can expanded gamut color satisfy a market which has grown used to spot color? Process color often mixes more than two primaries which reduces brilliance and tends toward producing browns, grays and muddy colors. Textile printers, on the other hand, can precisely target desired hues with spot color. When will the Canon system be able to print cotton-polyester blends? When will Canon offer pigment-based inks? Canon could certainly obtain pigment textile inks for its printer which could print blends. This would also enable workable in-line curing and cutting solutions. The market success of the Canon printer awaits an answer. Its first installation in Kyoto is reported to be successfully printing fabric, but it is to early to predict its market acceptance. No one can doubt, however, Canon's technical achievement and its value as an integration model.

Seiren

In the early 1980s, Japan's largest textile printer, Seiren, headquartered in Fukui, began the development of digital textile printing systems for its own operations. In 1989, Seiren completed the construction of its digital textile printing facility. By 1991, Seiren was printing production fabric with its piezoelectric printing system. The early printers employed Sharp piezoelectric print heads, print at 180 dpi along the width and as much as 360 dpi along the length. By 1996, Seiren reportedly was using about 250 piezo devices to produce $100 million in digital printing sales, or about one sixth of its total sales volume. Seiren reports its ink jet operations can produce about 500,000 meters/month.

Seiren calls its integrated digital design, printing and production operation the Viscotec's system. It distinguishes itself from others in that it has been printing short production print jobs for over six years. It uses spot color which can match any specified color. Its piezoelectric print heads do not require salt additive as does continuous ink jet inks or does it use color altering heat as does thermal ink jet and electrostatic printing. It integrates hardware, software, print chemistry and material through its computer aided design (CAD) and its computer aided manufacture (CAM) systems. Seiren devoted much of its efforts to developing these systems which integrated the best of CAD/CAM systems with database management for designs and ink mixture. As a printing company, Seiren developed a system with its customers' requirements in mind. Reportedly, the Japanese Automotive Industry's demand for just in time delivery for personalized automotive fabrics and the general industrial and retail movement toward reduced fabric inventories were influenced Seiren's decision to develop digital printing. Also, as commodity fiber and fabric manufacturing and printing gravitated to developing countries, such as China, Korea, Malaysia, Indonesia and others on the Asian Pacific Rim, Japanese textile industries began focusing their efforts on developing high value added specialty fibers, fabrics and short run customized printing. This proved particularly farsighted and enabled those companies such as Seiren to weather the economic storms which have battered the textile industries of developed countries. Fiber and textile production in Pacific Rim developing countries have grown at about 3 times the rate of growth in developed countries. "During 1982-1994, Japan's imports of fibers, textiles, and fabricated products grew from $3.1 billion to $22.2 billion to meet more than half of the domestic demand. The trend is expected to accelerate, with import penetration reaching 70 percent by the turn of the century."

Seiren operates a number of retail outlets for its fabrics and fabric products. These "Viscotec" stores provide Seiren with direct contact with end users. For instance, its Viscotec center at Aoyama near Roppongi in Toyko serves as a CAD design interface with its market. Seiren also can maintain computer connections with its clients' design departments. Its customers can order designs on bolt fabric or manufactured garments from remote locations via internet/telephone line transfer of instructions and designs.

Designers at U.S. apparel manufacturer Jantzen cited Seiren's ability to match any color exactly for both proof and production print as unique and highly desirable. These designers send their art and instructions created on their computer in Portland, Oregon to Seiren in Japan electronically. Seiren can match color with computer controlled analysis, its extensive database of dye mixtures, and color kitchen. As with conventional fabric printing, Seiren matches dye type to fabric fiber content: fiber reactive dyes for cotton, silk, linen and rayon; acid dyes for silk, wool and nylon polyamide; disperse dye for polyester, and other synthetics. These inks require fabric preparation and post processing and fixing as with conventionally dye-based printed fabrics.

Seiren sells its fabric for about two to three times the cost of similar conventionally printed fabrics. Seiren suggest that these fabrics are for applications with high profit per unit of fabric area, such as ties, scarves, swimsuits, and specialty sportswear like ski jackets. A sufficient number of customers value the unique characteristics of these fabrics or their printing process to pay more for them. These characteristics include brilliant color, no trapping, color proofs which match prints exactly, economical short runs, fast turn around, fast and secure computer design transfer and communication.

Seiren has created successful production digital textile printing systems for most fabrics. It has accomplished this with integrated systems and available, but not advanced, head technology. Seiren concentrated on CAD/CAM systems which could help customers realize their wishes and instruct production. The emphasis on CAD/CAM, databases and communication software was essential for communicating accurately among all of the production elements including designers and customers. It also facilitated Seiren's ability to archive and retrieve production records making the precise reprinting of previous jobs possible. Despite the pre- and post-processing cost and the slow speed of the print devices, Seiren experiences cost saving with its digital textile printing process due to low energy usage, minimal pollution and personnel. This company's digital mission did not rely on the success of one type of ink jet head. This system was not print head dependent. Seiren satisfied customer quality and quantity demands with many slow piezoelectric technology, rather than a few fast state of the art machines. Seiren concluded that the printing peripheral was just one part of a system and not the focal or most important part.

Seiren designed its system to supply the color quality the market had grown to expect. It uses spot rather than process colors. This sets it apart from other printing systems and is a key to its success. It enabled Seiren to provide the high color quality and full color gamut which conventional textile rotary screen printers normally supply and the market expects, without rotary screen printing's costly and time consuming screen making and burdensome screen storage, and its trapping. Process color solutions provide limited gamut and often compromised color quality.

The lesson of Seiren is that one can assemble a profitable digital printing system with current technology if one is committed to making it happen and emphasizes system integration, responding to customer demand and communication. Seiren did not allow the slow printing speeds of 1990 piezo printers prevent it from production capabilities with digital printing. It just built more printers to produce the desired production volume. Seiren designed and built a successful market responsive digital textile printing system. Its use of spot color and state of the art CAD/CAM with design and ink formula databases sets this system apart from other models. Its computer communication system translates information so as to make it compatible with all system elements and customers' computers. Seiren pioneering efforts distinguish it from other equipment developers due to its market and printing technology knowledge.

Stork

In 1991, Stork Screens B.V. of Boxmeer, Holland introduced its 4 color process TruColor printer TCP-2500 continuous ink jet proofing system. This device is similar to Scitex Iris's 4 color sample proofing system in employing fine droplet Hertz technology to generate high apparent resolution prints. In the Fall of 1995 at ITMA in Milan, Stork introduced its TCP-4000 series of 8 color Hertz continuous ink jet textile proofing devices. The TCP-4001 prints discrete 690 x 1020 mm fabric samples. The larger TCP-4002 prints 1020 x 1850 mm images. All of the TruColor printers use traversing print heads, and subtrata mounted on rotating drums.

Stork claims that its dye will print cotton, silk, viscose rayon, polyamide (nylon), linen, polyester, wool, and blends. The reactive dyes will fix to cellulosic and protein fibers for wash and wear fastness. The 8 color TCP-4000 series prints 4 color process dyes , cyan, magenta, yellow and black, in addition to golden yellow, orange, red and blue. Stork has claimed that this system can match almost any mix of colors which its 12 spot color rotary presses can print. 4 color process systems can address about 60% of the visible color gamut. Expanded gamut systems can match approximately 75 %. Spot color systems, on the other hand, can match virtually any color, including those containing specialty fluorescent colors. When one mixes more than two process color primaries, the color moves toward gray or brown. Also fiber reactive dyes tend to lack hue intensity and saturation.

Due to the small size of Hertz continuous ink jet orifices, about 14 microns in diameter, and their high frequency of droplet generations, over 100,000 per second, Stork and Iris do not recommend or supply any pigmented ink for their systems.

Also at ITMA 95, Stork demonstrated its "Fashion Jet", which was a joint development project with Zeneca, Felix Schoeller and KBC. The European Community funded its development with a EURAM grant. The "Fashion Jet is a prototype demonstrating the possibility of textile web printing. It employs a 4 color Hertz continuous ink jets mounted to a traversing carriage to print full color images with dye-based inks on a 1.4 meter wide web of fabric at a rate of 5 running meters per hour.

In January of 1997, the European Community granted Stork in partnership with Zeneca a grant to develop a new and faster continuous ink jet system for textile printing. Stork is also reported to be examining piezoelectric printing systems as well. The European Union's grants promote cooperation between companies within member countries. Such inter-company ventures mix significant cultural and language differences which can interfere with cooperation and integration. The company to serve as the prime integrator usually accrues the greatest benefit, sometimes to the chagrin of its partners.

Stork is the largest manufacturer in the world of rotary screen printing systems for textile decoration. It is estimated that rotary screen printing accounts for about 63 to 64% of the world's textile printing. Stork has announced in 1995 that it viewed digital printing as an appropriate technology for sampling and proofing, but not for production printing in the near future. On one hand, Stork did not wish to encourage technology which might displace its core business. On the other hand, Stork is committed to maintain its market position and supply its customers needs. As the market shifts to minimum inventory business strategies with consequent smaller orders and faster turn around for textile printing, the textile printing industry has begun to seek short run digital printing solutions. Also, designers are looking for printing technology without the repeat design size limitations of rotary screens. Digital web textile printing could provide large panoramic designs without repeats for bed linens, drapery and other home furnishings and textile murals.

Stork produces high quality sample proofing systems which complement its high production rotary textile printing with match to print capability. Stork has adapted its proofing model for production printing. Its reliance on process colors and slow Hertz ink jet engines, however, does not agree with the market requirements for production digital printing.

Toxot

In 1994, Embleme assembled a continuous ink-jet garment printer using Toxot multi-level continuous ink jets printing Toxot 4 color process water-based UV curable inks. Embleme operated this device for two years printing mostly T-shirts for its local retail market. Embleme was unable to sell production models of these printers. It pointed to the high print head cost as causing market resistance. Its under financed marketing efforts, the loss of growth in the garment printing market and capacity saturation might also have figured in the lack of market interest. Toxot, however, has produced studies and analyses to buttress its claims of economic and functional viability for its continuous ink textile printing system.

The Toxot researchers had integrated most of the elements for a functioning system. Toxot has responded to color intensity concerns with a thermally cured pigment loaded water-based ink system with improved wash characteristics. It adjusted its software algorithms to substantially reduce banding. It offers a 180 dpi system in addition to its 120 dpi system to address resolution concerns.

Toxot has lacked the necessary marketing and financial commitment to bring its printer to market. Its other commitments have demanded its resources. Those projects also have customer financial backing which its textile developments have lacked. Unlike Canon, Toxot does not have such large R&D and marketing budgets. Like many R&D operations, Toxot has relied on application developers and users to fund its research activities. A large European vinyl floor covering company has underwritten its work on adapting multi-level ink-jet for printing rolls of floor covering. Toxot is assembling a 2 meter wide printer consisting of 6 color dedicated fixed arrays on a material transport web. This device prints continuously as the vinyl moves beneath the six fixed arrays. The multi-level ink-jet permits the knitting of print bands to avoid visible banding on the printed surface. Other ink-jet systems must traverse printheads with respect to the print surface or have multiple arrays of the same color to accomplish this. Traversing arrays of printheads have a practical production speed limit of 2 to 3 running meters per minute for 1.6 meter width bolts. Toxot designed its vinyl floor covering ink-jet fixed array to print 2 meter wide vinyl at the rate of 20 running meters (or 40 square meters) per minute. Toxot has devoted much of its technical and human resources to the implementation of this project, which is now projected to begin production in the beginning of 1998.

Toxot could adapt its large fixed array ink jet printing system for production web textile printing. Toxot could address objections and market resistance due to its low resolution by trading some of its speed advantages which exceed the needs of one production line modular sewing unit, for improved resolution. A system with 120 dpi heads can produce 240 dpi resolution along the fabrics running length by adjusting droplet deposition and reducing throughput speed to10 running meters per minute. In similar manner, 180 dpi heads can print at 360 dpi along a textile's length.

The importance of the Toxot model lies in the high production speeds of its system and its washfast inks. Toxot's parent, Imaje, has almost a decade and a half of ink jet technology and market experience. These textile systems lack the necessary textile industry financial backing to bring them to fruition. The initial cost of these heads is somewhat offset by their high reliability. Industries, however, are requiring faster return on investment computer controlled printing equipment, however, in anticipation of rapid obsolescence.

Digital Textile Printing Systems Development Failure Modes

Disintegrating System. When the parts do not mesh, when the system does not easily accept differing file or platform formats, when one can not exchange data with designers and customers, when inks clog print heads, when inks are not fast against cleaning, wearing, and exposure to sunlight, when print heads can not maintain registration, when print drivers or raster image processors can not control print heads to produce the desired image quality, when users do not have adequate training, in short, when the system is not integrated its operation fails. System development can fail due to technical limitations or inconsistencies, ineffectual communication or incompatibilities among project partners.

Inadequate Time. The clock does not stop. Time is a critical factor which developers can easily overlook or underestimate. Technical engineering tends to account for the fourth dimension, time, inadequately. Once a system achieves a production objective, engineers often consider their job completed. Corporate desire to rush product to market too often limits the time allowed for alpha and beta product testing. Initial product releases often are beta versions with their expected glitches. Examples of such failures abound, particularly where systems integration is concerned. For instance, manufacturers of print heads have had ink systems developed for their heads which will perform satisfactorily in the short run, only to produce failure modes after months of use. A number of explanations for these failures can adequately explain them. These include the aging of inks and toners, the long term build up of ink residues around functioning components, and seasonal environmental changes. Their failure underscores the need for a close relationship between ink and head manufacturers in the integration of printing systems and adequate time for testing.

Inaccurate Timing. For development projects in a competitive environment, timing is critical in bringing product to market. Products can fail to win adoption because they appear before conditions favoring market adoption exist, or after the competition has saturated the market with similar offerings. Developing systems so as to come to market at the right time requires a particularly powerful crystal ball and an ability to estimate the pace of system development accurately. Project management offers reasonable structure and tools for executing projects and estimating the time needed to complete them. Estimating is an area where experience can help to improve accuracy. In the consumer market, one product can depend on another for the formation of a market critical mass. The broad market adoption of video players awaited the release of movies in video format. Initially, the movie industry big studios resisted releasing movies as videos until copyright issues were resolved and a critical mass of video players were in the market to justify their developing it.

Timing figures critically in the adoption of new industrial processes and the marketing of products. Pioneers often encounter the bleeding edge of expensive trial and error learning, but also can win a large and primary market position. Early adopters often benefit from the pioneer experience. This level benefits from pioneer agony while still enjoying early market position. Some would call this the cutting edge.

Inadequate Finance. Developing systems often requires more funding than originally planned or invested. Projects which incubator industries create are usually under funded and often fail unless they can attract funding and investment. Larger enterprising companies frequently purchase incubator companies and their projects. This can invigorate the larger company with new ideas and opportunities while providing necessary financing for the project.

Inadequate Color. Process color can not match the full gamut of available textile colors. Fiber reactive dyes used in many digital textile systems lack the vibrancy of acid dyes for printing on silk and wool. Ink jets deposit thin layers of ink which are vulnerable to abrasion and fading.

Insufficient Speed and Profitability. The payback and profitability of a printing system depends on its ability to produce enough value to pay for itself, its operation and maintenance and produce profit.

Inadequate Technology. If a system's inks clog its nozzles, if its print heads fail frequently in the middle of prints, if one can not reproduce colors from one day to the next, if the system does not perform as advertised, one is likely looking at a hardware, software or chemistry failure.

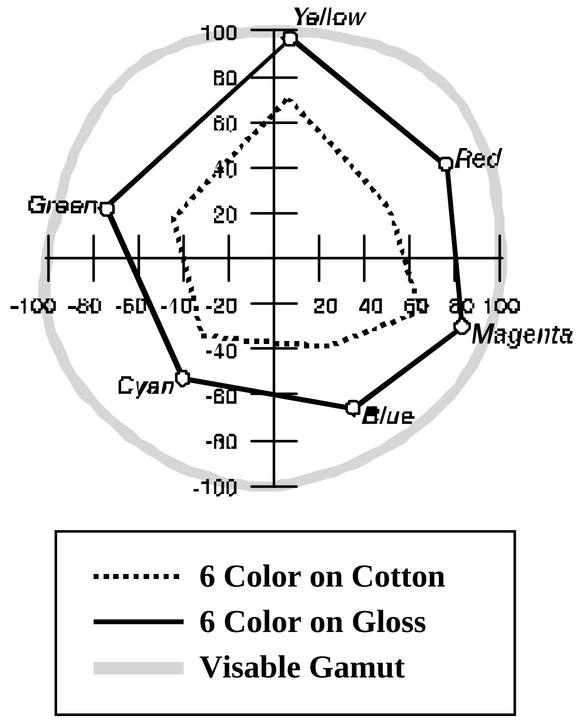

Fig. 3: Six Color Process Gamut

Textile Printing Segmentation

The textile market's has segmented its textile printing needs into Proofing, Sample, Coupon, Catalog and Production segments. Proofing is the printing of a design in quantities of one or a very few to assess a design and its color. Sampling performs much the same function as proofing for a particular application, such as a sample garment. Coupon production is enough to provide swatch samples of a design for sale development. Catalog printing is printing of sufficient quantity to satisfy catalog production and marketing needs. Production volumes are those necessary to satisfy market demand. Typically proofing and sampling involve under 5 meters, coupon under 30 meters, catalog about 100 meters and production begins about 300 meters. Market demand and industry requirements are modifying these segments. A new model segmentation is evolving to satisfy new industry needs and channels. A recent report suggests redefining these segments for digital textile printing, combining Sample & Coupon, while adding Personalization, Customization, Agile Manufacturing, Short Run & Rapid Response and Production Substitution. Personalization is the individualization of a print, usually finding application in the printed sportswear, souvenir and premium markets. Customization permits customers to chose design aspects of textiles and textile products before printing. Agile Manufacturing involves the integration of textile printing and apparel and sewn item manufacture. Short Run and

Rapid Response is the printing of fabric in direct response to orders much like agile manufacturing without the integrated cutting and garment assembly steps. Production Substitution would occur with print production rates above 10 meters per minute.

Stork, Iris, Encad and HP printers are currently providing design proofing and sampling to the textile industry. These devices have a number of limitations including process color and wash fastness limitations. Stork does supply a steaming device for fixing its dyes and achieving washfastness. Both Encad and HP printing systems can also print pigmented inks. Pigment textile printing accounts for about half of all textile printing.

Many transfer printing systems, both digital and analog, provide are supplying personalization printing needs. The Embleme/Toxot and DIS "Revolution" thermal ink jet garment printing systems also provided personalization. A number of digital piezoelectric ink jet garment printing systems using capable of providing personalization are scheduled to arrive in the market before the end of 1998.

Seiren's Viscotec's Square is the first to offer consumer controlled customization of textile applications. In effect, the order giver, customer and designer, chose designs, patterns, sizes, fabric type and colors. Such customer interfaces can provide varying degrees of guidance as needed. Seiren has demonstrated the practicality and popularity of such choice at their Viscotec's design centers in Japan. The Viscotec's model suggest opportunities for retailers and producers of textile items alike.

Agile Manufacturing is approaching implementation as a demonstration featuring the Canon Bubble Jet Textile Printer and the design and modular sewing plant at TC^2 in Cary, North Carolina. Agile Manufacturing and Short Run and Rapid Response companies will seek faster, more versatile, less expensive digital printing devices to address all fabrics with a wide selection of ink colors and types.

The Toxot fixed array continuous ink jet systems is the only proposed digital configuration which could supply production speeds in excess of 10 linear meters per minute per machine. Seiren achieves high production rates with multiple printing devices operating simultaneously.

Market Demand and Digital Textile Printing

The way industry, designers, retailers, and end-users order textile printing is changing. Everyone is trying to reduce their risk and, in doing so, their inventory. The textile printing industry, used to bulk printing and large print runs finds its conventional analog printing systems unable to supply the quick response just in time delivery being demanded of it. Digital textile printing offers the promise of providing that quick response.

People are increasing discovering new way to express themselves in the fabrics they wear and with which they decorate their world. Retailers and internet marketers could offer customers affordable options such as design choice and custom tailoring with integrated digital printing and marketing systems similar to those which the Seiren model suggests.

Market Requirement for Digital Textile Printing

Customers want what they are receiving now or better. Digitally printed textiles must be at least as color fast, have the image quality, color range and brilliance now available from analog printing methods like screen printing. 4 color process and expanded gamut printing systems can supply some niche markets such as personalization and proofing, but they will have difficulty winning acceptance for short run-quick response and production printing. Spot color or expanded gamut with spot color systems are necessary to fulfill customer color expectations for most textile printing. End-users will also want UV resistant pigmented inks for many applications where textile experience sun exposure.

Textile printers are looking to satisfy customer needs profitably. Printing systems need to be able to produce at a sufficient rate to meet demand and recover investment within a reasonable period. Whether it is with a few fast and more expensive printers or many less expensive slower ones, digital print systems will not win market adoption unless their potential purchasers imaging they can profit with them.

In short, customers want what they have plus more. In so far as digital printing systems can supply it in a way that their owners will profit, they will win adoption.

Digital Textile Printing Models For A New Market

Digital textile printing offers opportunities for replacing conventional fabric printing, in addition to opening new opportunities of printing. Increasingly companies are discovering that digital processes and technologies can supply their market's needs for quick response and just in time delivery. Textile printers are employing the unique characteristics of digital printing systems to personalize, sample designs or even print short runs cost effectively. Digital web textile printing also can produce continuous images without the limitation of repeats. This creates new design and high value added market possibilities including panoramic bed sheets, window and wall coverings. Designers want the option of printing both with and without repeat. Digital web printers permit images the length of the roll. Digital file and print driver processors permit tiling widths of printed images. Designers appreciate that digital printing came eliminate undesirable trapping, i.e. the bands where colors overlap. The textile industry wants these opportunities and the others which digital printing offers.

One model will not fit every printing need. A production textile printing model will have to include spot color printing and a color kitchen system while novelty garment printing continue to satisfy customers with process color. All models, however, will require certain common elements and characteristics. They include:

- User friendly interfaces and ergonomic designed work stations, keyboards, stylus pads and other design tools.
- Translation for customer graphics formats.
- Effective and easy to use inter and intranet communications
- Easy to use graphics generating programs
- Training
- Production speeds which are sufficient to operate profitably and pay for the machine and its maintenance within an acceptable period of time
- Controllable and consistent color
- Color fast inks which will withstand crocking, washing, and UV exposure. Some will also have to withstand dry cleaning as well.
- Print without repeat to the size limitations of the print device
- Affordability and profitability

Agile manufacturing, short and long run production printers will also have to include addition capabilities:

- Reproduce the broad spectrum of color
- Print spot color or expanded gamut plus spot color
- Capable of printing dye and pigment-based inks
- Rapid color change with minimal ink wastage per system flush
- Capable of printing the commercial range of fiber types and fabric thicknesses
- Print roll to roll or roll to cut pieces
- Dimensionally stable material transport system
- Minimum print output of 1 to 3 meters per minute from one or more printers
- In-line curing and fixing
- In-line fabric cutting for agile manufacturing printing mode
- On-going monitoring, measuring, testing, correcting, adjusting and recalibrating

In addition, full production machines will:

- Print at 10 running meters per minute
- Match any screen print color
- Likely will print from a fixed array or one with minimal movement for maximum throughput

A production digital printing device may have more than one type of print head. For instance, piezoelectric or continuous ink jets may be combined with airbrush for coarser ink particle depositions such as metallic inks.

Conclusions

The market demand for textile printing is changing. Integrated digital printing systems can meet many of those demands. The task of constructing integrated systems is complex involving many discipline, expensive requiring considerable funding, and challenging demanding that developers listen to their customers and imagine ways to create what they want.