Information Technology Vision for the U.S. Fiber/Textile/Apparel Industry

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ABSTRACT

The fiber/textile/apparel (FTA) industry is one of America's largest manufacturing industries, and its success is critical to the economic well-being of the country. In terms of technology, the industry is very sophisticated, and in fact, each of its three sectors is the most productive in the world. However, the industry has been challenged by an onslaught of imported products. The most serious economic threat of foreign competition is to the apparel sector, which is the least capital intensive of the three industry sectors. While steps to address the challenges to the FTA industry include technological, sociological, and economic efforts, this paper focuses on efforts employing information technology.

The nationwide capacity must be created that can enable and sustain the production of world class FTA products that are reasonably priced and are responsive to consumer demands. An enterprise framework, product data standards, and improved design practices are the information technologies that will enable the required system to be developed. In turn, these technologies will assist in the implementation of design-driven, multi-enterprise, concurrent engineering as well as demand-activated manufacturing.

The effort required to realize the new vision for the FTA industry is huge and requires participation from all sectors of the industry, as well as government, academia, and professional societies.

KEYWORDS

apparel; concurrent engineering; demand-activated manufacturing; design; enterprise framework; information technology; product data; quick response; textile

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1. INTRODUCTION

The fiber/textile/apparel (FTA) industry is one of America's largest manufacturing industries, and its success is critical to the economic well-being of the country. In terms of technology, the industry is very sophisticated, and in fact, each of its three sectors is the most productive in the world. However, though it was once the world's unchallenged leader, the industry has faltered in recent years, and it is in danger of slipping further. This paper describes reasons for the FTA industry's decline and information technology-based strategies for strengthening it. The intent of the paper is to present a "strawman" that the industry can use to develop a unified, national technology-focused strategy to strengthen the FTA industry.[1]

The author developed his ideas over the last two years while developing product data standards for the apparel industry under sponsorship of the Defense Logistics Agency. (See Appendix B for further information concerning the involvement of the National Institute of Standards and Technology with the apparel industry.)

In addition to Appendix B, three other appendices contain information referenced in this paper. Appendix A lists the bibliographic references used; Appendix C contains a glossary of definitions and acronyms; and Appendix D lists the organizations involved with the FTA industry mentioned in this paper.

2. THE CHALLENGE TO THE FTA INDUSTRY

[1]Although this paper focuses on the fiber/textile/apparel industry, much of the analysis is applicable to the more general fiber/textile/fabricated products industry.

The U.S. FTA industry is the largest nondurable goods industry in the country. Ten percent of all employees in the U.S. manufacturing sector work in this industry, making it larger than the automobile, steel, and chemical refining industries combined [OTA87, DIE90]. The value of U.S. apparel and textile products shipped in 1990 was 128 billion dollars [ITA91].

A thriving, successful FTA industry is important to the economic well-being of the U.S. The total employment in 1990 for the U.S. FTA industry was 1.67 million people [ITA91]. Furthermore, employment in other industries is linked to a healthy FTA industry. For every three new jobs created due to increased productivity in the FTA industry, two more were created in other industries due to "ripple effects" [OTA87].

Compared with other manufacturing industries, the FTA industry employs a higher percentage of women and minorities. Women made up 77 percent of the FTA workforce in 1989, compared with 33 percent for all manufacturing. Minority workers had about double the representation in the FTA industry as in manufacturing as a whole [ITA91]. Unfortunately, most production skills required for the FTA industry are very industry-specific and are not easily transferable.

In recent years, the FTA industry has been in decline, and it is in danger of slipping further. Contributing to its past success is the strong U.S. marketplace. In 1989, personal consumption expenditures on apparel in the U.S. was $170 billion [AAM90-1]. However, imports have been chipping away at the market. Apparel imports have gone from 2 percent of the American marketplace in 1963 to 50 percent by 1985 [OTA87, DER89]. In 1989, apparel imports increased 16 percent, and were valued at $20.9 billion wholesale [AAM90-2]. Our domestic apparel manufacturing industry is under siege from imported products.

As a byproduct of this siege, 282,000 jobs were lost in the first half of the 1980s in the FTA industry [DER89]. Furthermore, it is estimated that imports "may account for well over one million lost job opportunities, not to speak of the additional million lost through 'ripple' effects" [OTA87].

The apparel sector[2] is the weakest link of the entire FTA industry. It is currently the most labor intensive of all three sectors, and consequently is at greater risk to foreign competition (due to lower labor costs) than the fiber and textile sectors. However, because of

[2] The phrases "apparel sector" and "apparel industry" will be used interchangeably in this paper.

the dependencies of all sectors on each other, failure in the apparel sector could hurt the entire industry. It is in the interest of the entire FTA industry for the apparel sector to succeed. Furthermore, the entire system, including fiber, textile, apparel, and retail, must be addressed to strengthen the industry.[3]

3. WHY HAS THE FTA INDUSTRY DECLINED?

The U.S. FTA industry has not competed successfully in the labor-intensive commodity market, characterized by low quality and low price. The commodity part of the industry appears to be irretrievably lost to imports [DER89]. When measured in square meters, 33 percent of the U.S. textile market and 48 percent of the U.S. apparel market was imported in 1985. But, in dollar terms, only 6 percent of textiles and only 20 percent of apparel was imported. "The difference between dollar and volume measurements can be attributed to the continued ability of U.S. firms to compete in markets for high-quality, high-price products" [OTA87].

The U.S. fiber and textile sectors have greatly improved their operations, converting them from labor to capital intensive. There is no reason to believe that the fiber and textile sectors cannot compete in the commodity market with high quality products.

Mass production, by employing fixed automation, is geared towards producing commodity products and has not taken advantage of the knowledge and skills of the "old world" artisans [WIL92-1]. Before the industrial revolution, artisans understood all aspects of apparel product development from design through manufacturing, and applied that knowledge in conceiving and developing new products. With the advent of the industrial revolution, the paradigm changed as mass production allowed the U.S. to become the premier industrial power in the world. Each employee knew a limited task without understanding his or her role in the total development cycle. Mass production served the U.S. well, as the rest of the world was years behind in modernizing its industry, and the U.S. could dominate in low cost, commodity products. However, the world has caught up, and fine style and high quality are now the determinants for successfully competing. Flexible automation, rather than fixed automation, is necessary to produce superior products efficiently, in particular, in the fashion market.

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[3] This paragraph is paraphrased from remarks of Tom Malone, President of Milliken and Co. and Chairman of the National Technology Center Oversight Committee, at the Department of Energy (DOE) Critical Technologies Workshop, Berkeley, CA, May 28-29, 1992.

Although automation has improved productivity, a comprehensive vision of how it will help the industry has not been developed. It is often assumed that automation will improve productivity and therefore remove the advantage that foreign companies have due to lower labor costs. The assumption is that automation will require fewer employees, and that the employees left will be paid less, because automation will effectively deskill[4] the employees required. However, this assumption is incorrect. As discussed later in this paper, the FTA industry of tomorrow will become more sophistocated technologically, requiring higher skilled employees at all levels who are empowered, not deskilled by automation.

Low wages will not enable the U.S. to maintain the superior labor force needed. Furthermore, the brightest of the nation's new employees will not be attracted to an industry that is degrading the skills required and lowering its already low wages. Using automation to improve productivity is essential, but it must be part of a broader plan that takes into account the health of the entire industry.

The U.S. educational system has not provided the level of training and education necessary to meet the needs of the FTA industry. Properly prepared employees are required at all levels of the industry–from production to technical to management. Historically, entry level employees have been trained as apprentices by the industry. The situation has started to change, as the educational system has begun to address industry needs for skilled workers.

The level of technical sophistication necessary in the FTA industry is very high. In fact, a unique combination of skills are required, including those from the manufacturing, engineering, computing, and artistic disciplines. There is no other industry where the rare combination of engineering and art skills plays a more prominent role. Meeting the needs of the FTA industry of tomorrow will require employees with superior skills and knowledge.

Communication barriers have existed among the different sectors of the U.S. FTA industry. For the most efficient operation, the fiber, textile, apparel, and retail sectors must communicate effectively. For example, the operations and policies of an apparel manufacturer are heavily dependent on its suppliers, and vice versa. However, the terminology used by different sectors, or even by different companies within the same sector, is often different. A single company can improve its efficiency only up to a point because,

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[4]The *Dictionary of Administration and Management* [BAN81] defines "deskilled" as, "a term that refers to simple tasks or jobs, which, as a result of work simplification or other reasons, require little or no skill to perform. Also said of persons who perform such tasks or jobs."

ultimately, it is dependent on others to which it has limited control and access. If standards were developed that allowed better communications, companies could work together to improve the overall efficiency of the entire industry, improving each company's individual efficiency as a natural by-product.

The desire among industry sectors to improve communication has led to the establishment of a number of trade organizations. These include the Textile-Apparel Linkage Council (TALC), the Sundries and Apparel Findings Linkage Council (SAFLINC), the Fabric and Suppliers Linkage Council (FASLINC), and the Voluntary Inter-industry Communications Standards Committee (VICS). These associations were heavily involved in developing "Quick Response" for the FTA industry and developing the Electronic Data Interchange (EDI) standards[5] necessary for it. The EDI standards are limited in the information they convey, but they are a good starting point for industry communication. Most importantly, they enable Quick Response.[6]

Consumer needs have not been addressed as well as they should. As an example, the bar codes used for Quick Response enable industry to determine what items consumers are buying, but the codes do not contain sufficient information for tracking style trends. The hypothetical question, "what style of shirt collars are consumers buying this season?" cannot be gleaned directly from the bar code information. Yet, the answer to this type of question is useful to designers who need to design what people want. Providing the means to gage consumer wants and entering those into the system is important [WIL92-2].

A second example concerns "fit." An important selling point for a garment is good fit. Nevertheless, a common consumer complaint is the difficulty in finding clothes that fit well and look good. This is a consequence of current sizing systems. "Current sizing standards

[5]The Electronic Data Interchange Association has been publishing information about U.S. EDI industry standards since 1968 [EDI90].

[6]"Quick Response is a strategy to reduce the time needed to get from raw material to point-of-sale in a retail outlet and to reduce the amount of inventory in the [retail/warehousing/manufacturing] pipeline" [WEI92]. To implement Quick Response, bar codes containing information represented by the EDI standards are placed on raw and finished materials throughout the manufacturing and distribution cycle. Scanning the bar codes enables industry to track the progress of the materials throughout the cycle. Knowing where the materials are at any point in time enables the production and distribution processes required to be timed to reduce the overall cycle time and inventories.

rely on obsolete body measurement databases. Body forms used to translate sizing into garment styles do not represent potential consumers' body dimensions, contours or posture" [SAL89]. Further exacerbating the fit problem is that there is often no consistency in apparel size designations [GOR91].

The U.S. apparel industry has not taken needed steps to compete effectively in the global community. A key barrier to international trade is the U.S. industry's exclusive use of the English system of measurement; the rest of the world uses the metric system. Switching to the metric system is essential to compete globally in the future. However, American industry has resisted. It is not enough to convert sizes based on the English system of measurements to metric. Consumers in other countries are used to seeing sizes expressed in whole numbers of metric units, not fractional units as a consequence of conversion from English units.

Furthermore, size designations for ready-to-wear garments are often arbitrary, generally based on one or two dimensions of the garment. The dimensions often differ among manufacturers and/or among countries. This is one reason that different garments with the same size designation will fit very differently proportioned people. However, the European community is currently working to standardize on size designations [PAD91]. The U.S. needs to be involved in this activity.

Funding for research and development has not been adequate. The U.S. FTA industry itself invests a relatively low amount in research and development (0.5 percent of sales versus 2.8 percent for U.S. manufacturing as a whole in 1985) [DER89]. The low research expenditure is due in part to the fact that a large segment of the industry consists of small companies, unable to realize the payoff from a large research investment. Federal research funding would be very helpful to provide the support base that the FTA industry needs. However, the funding support has not been forthcoming. Despite the fact that the FTA industry dwarfs the semiconductor industry economically (as shown in the data below), it has received insignificant support relative to the semiconductor industry [ITA91].

The low level of government funding support is in sharp contrast to the support given to the FTA industries in other countries. South Korea is investing in its textile industry to make it

Industry	SEMICONDUCTOR	TEXTILE (SIC 22)	APPAREL (SIC 23)
Shipments (billions of $)			

the dominant power in the world.[7] Likewise, Japan has invested in a large program to develop sophisticated apparel making equipment.[8] In 1980, Japan was not a significant factor, but now has a strong FTA industry.

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[7]The London Financial Times reported on November 28, 1989 that South Korea will provide $4 billion in aid to its textile industry to modernize plants with the aim of becoming the world's biggest textile exporter by the end of the century.

[8]Professor T. Soen, retired from the Kyoto Institute of Technology in Japan, described the Technology Research Association for an Automated Sewing System (TRAASS) program at the Bobbin Show, September 17, 1992. TRAASS was a national R & D program in Japan that ran from 1982 to 1990. The Japanese government funded the program at $60 million, and 28 Japanese companies (including sewing machine, textile, and apparel manufacturers, dyeing and finishing companies, computer and robotic machine companies) participated, contributing their resources.

4. WHAT NEEDS TO BE DONE?

The efficiency of the entire FTA complex (including retail) must be improved. Communication inefficiencies cause the time to market from fiber production to finished garment on the retail shelf to be excessive. The time delay directly contributes to an annual loss of $25 billion in the FTA complex due to markdowns, stockouts, and inventory cost.[9] Regarding the FTA complex as a single, integrated system and improving its overall efficiency is currently a major interest of the industry.

Special attention must be given to improving the efficiency of the apparel sector, because it is the most labor intensive of the three sectors, and therefore faces the greatest threat from imports. Automating apparel manufacturing activities on the production floor is an obvious method for improving the efficiency of apparel manufacturing. However, improved design engineering can have a more significant impact, as will be discussed below. Unfortunately, interest in improving the efficiency of the apparel sector through improved design engineering has not been strong, and accordingly is emphasized in this paper.

The U.S. apparel industry must produce world class apparel products that are responsive to consumer demands. The phrase "world class apparel products" refers to high-quality apparel products that are designed for the entire apparel product life cycle. In other words, not only function and style, but also manufacturability as well as other life cycle concerns, must be designed directly into the product.

For the apparel sector, the commodity and fashion markets must be considered separately, because the needs for the two are different. The key determinants for success in the commodity market are based on producing apparel products as quickly and inexpensively as possible. Alternatively, the key determinants for success in the fashion market are based on producing apparel products with high quality, excellent fit, and especially, quick response to style changes.

The fashion market is worth special attention. According to the American Apparel Manufacturers Association (AAMA), apparel consumption demand is shifting toward higher quality, higher styled, longer life apparel at a higher price. Market analysts portray today's apparel consumer as a comparatively independent shopper with a more sophisticated taste level, a higher income level, and a higher education level than previously [OTA87, AAM84].

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[9] See footnote 3, page 3.

Other countries have been very successful in producing high quality apparel products in market niches and have been very successful. For example, "both Italy and Germany operate in market niches in which they experience relatively little competition from low-cost producers" [DER89]. It is interesting to note that West Germany is the world's third largest textile exporter, despite wages that are substantially higher than those in the U.S.

World class apparel products can be produced by capitalizing on our country's rugged individualism, an American attribute that is recognized worldwide. Creativity and innovation are cornerstones of American industry and have helped to establish its success in the past. There are 23,000 firms that comprise the American apparel industry, averaging just under 50 employees each.[10] They compete by offering different products and by being closely attuned to their customer base. If they could leverage available information and technology to improve design and production efficiency, they could wield a powerful force in the American marketplace. A network of small companies producing high quality, high style apparel tied intimately to the domestic market would be an awesome economic force with which to contend.

The power to leverage information can be harnessed by applying a new technology, multi-enterprise, concurrent engineering. "Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements" [WIN88]. Multi-enterprise, concurrent engineering extends this concept from the optimization of a design and production system to the broader optimization of an industrial system. "It is the optimization of all the enterprise's operations, including planning, marketing, and financial operations, as well as its transactions with its suppliers, distributors, and other business partners" [CAR91].

Design is the critical arena for concurrent engineering. In the durable goods industry, about 60 percent of a product's production cost is fixed very early in the process of design as illustrated in the figure below. Overall, the design process may fix as much as almost 90 percent of the total production cost of a product [KEL89].

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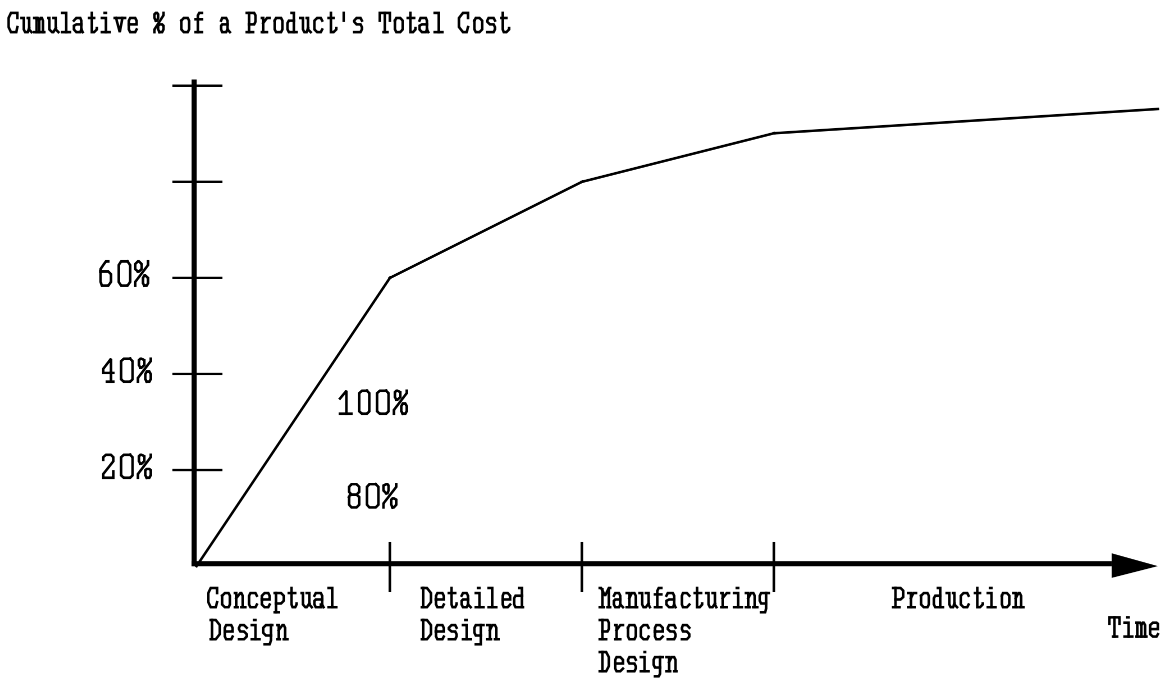
[10]This statistic was given in the remarks of Joe Off, Managing Director of Textile/Clothing Technology Corporation, at the DOE Critical Technologies Workshop, Berkeley, CA, May 28-29, 1992.



The cumulative percent of the total cost, or life cycle cost, of a product is shown as a function of the stages of the product's life. Early design decisions determine most of the ultimate cost. (Adapted from [KEL89].)

Design has the greatest impact on manufacturability, production cost, and product quality of any process in the apparel manufacturing life cycle. Accordingly, research concentrating on the design process can be more effectively leveraged than any other process in the life cycle. However, the apparel design process was found to be the most inefficient in the product's life cycle because of the lack of appropriate information and design tools [KSA89]. The design process itself needs to be studied for developing appropriate design tools and information systems.

Unfortunately, research and development related to apparel design is not being emphasized. This is despite the fact that government funding for FTA-related research and development has increased over the last several years. It should be emphasized that the increased funding level is still small when compared to the size and importance of the FTA industry, and also when compared to the funding support for other industries such as aerospace and electronics. Still, the new funding has enabled a number of new programs to be established.

The Defense Logistics Agency is sponsoring a substantial program to improve apparel manufacturing technology and to enable custom-driven manufacturing of uniforms.[11] The Textile/Clothing Technology Corporation[12] is conducting a large program to enable apparel on demand–i.e. to manufacture garments to custom fit and style preference at competitive pricing and quick turn-around time. Finally, the National Textile Center [WIG92] was established this past year to coordinate university research that spans the entire FTA complex–the first industry-wide research program to do so. Unfortunately, the in-depth study of apparel design is not being addressed by any of these efforts.

A national effort that establishes apparel design engineering as a serious engineering discipline can be a catalyst to enable some of the important changes that are needed in the apparel industry. The point has been reached where retailers, without particular design knowledge, are designing apparel. This is backwards from the approach that is needed. The solution, however, is not simple. To provide a system that will support design-driven engineering will take a massive effort that must involve the entire industry. Nothing less than a national effort is required.

There are many experts from both academia and industry who have good ideas for applying technology to improve apparel design engineering,[13] but they are not in position to initiate

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[11]Much of DLA's sponsored apparel research is published in the annual Academic Apparel Research Conference proceedings. The most recent conference was held February 17-18, 1992 [DLA92].

[12]The Textile/Clothing Technology Corporation ([TC]^2) is a non-profit consortium established in 1979 to pursue more effective methods and more efficient machinery to carry the apparel industry into the future [TC292]. Its mission includes demonstrations, education, and research and development. The National Apparel Technology Center, located in Raleigh, NC, is the primary instrument of [TC]^2's real time demonstration and other programs.

[13]One organization that is devoted to the research and teaching of apparel and textile design is the International Textile and Apparel Association (ITAA). This organization was originally established as the Association of College Professors of Textiles and Clothing (ACPTC). The scope of ACPTC was expanded in 1991, and its membership was opened globally, and also opened to include industry. Accordingly, its name was changed to ITAA.

needed actions. The means needs to be developed to empower these experts. Attaching the status of an engineering discipline to the unique blend of knowledge and rigorous training required for an apparel industry professional will amplify the voices of these experts.

5. HOW WILL THE RECOMMENDATIONS HELP?

Integrating the entire FTA industry electronically, including the retail sector, will improve the efficiency of the whole system. By developing a functional model for the whole system (referred to as an enterprise framework in this paper), the interfaces among the necessary_processes can be defined. Subsequently, product data standards that specify the information requirements for a product throughout the product's life cycle can be developed for the interfaces. With an enterprise framework and product data standards specified, much (if not all) of the system can be integrated electronically. The integration can greatly smooth communications and reduce costs throughout the system.

In fact, leaders in the FTA industry have advocated an approach that would utilize an enterprise framework and product data standards. Their goal is to enable demand-activated manufacturing, so that goods are pulled through the "apparel pipeline" from fiber to finished product based on customer demand. This is the opposite of current practice of goods pushed through the apparel pipeline based on manufacturers' anticipation of customer demand. Many FTA industry leaders believe that demand-activated manufacturing can recover a significant portion of the $25 billion a year loss in the apparel manufacturing pipeline.[14] An enterprise framework and product data standards are technology enablers for demand-activated manufacturing.

Improving the apparel design process, and integrating it into the entire product life cycle can have the effect of converting labor-intensive activities to capital-intensive activities. In the apparel sector, activities in the design room through pre-production are costly and labor intensive. Developing new design tools will amplify a designer's capabilities. More importantly, since the tools will be integrated within the product life cycle, they will enable a designer to develop better designs for manufacturability, for reduced material costs, etc.–all with less iterations before reaching the final design. Since the integrated tools depend on the installed, electronic, enterprise framework for much of their value, they will not be easily copied for stand-alone use by labor-intensive competitors.

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[14]This conclusion was reached at the DOE Critical Technologies Workshop, Berkeley, CA, May 28-29, 1992.

The conversion from labor-intensive to capital-intensive activities effectively means building intelligence into enterprise activities. Consequently, the term "capital intensive" should be replaced by the more appropriate term "intelligence intensive."

The three technology enablers–an enterprise framework, product data standards, and improved design practices–can be utilized to advance the FTA industry. All sectors of the industry, including the manufacturing and the retail sectors, will benefit. The benefits will apply to both the commodity and the fashion markets. In the apparel sector, improvements in the design process will have the greatest impact in the high fashion market. However, improving the quality of commodity products, and responding quickly to consumer demands will help in the commodity market as well.

Once the apparel sector is competing in an intelligence-intensive marketplace, the main determinants for success are based on delivering what the consumer wants. Many consumers want high quality, good looking, made-to-measure clothing, and as quickly as possible. The advantages of America's 23,000 separate apparel manufacturing companies over their foreign competitors come into play. Their advantages are their proximity to America's marketplace–the largest in the world–their knowledge of Americans' tastes, and their ability to meet small market niches. The proximity to market means quick turn-around, low transportation costs, and more responsive consumer relations. Also, it should be easier for American manufacturers to determine the needs of American consumers. Finally, a small market niche may provide insufficient revenues for a large company to pursue, but may be fully sufficient to sustain a small company's needs.

An improved industry will attract better employees to it, due to its superior compensation and opportunities. A superior employee is likely to produce better quality products. Better paid employees will produce a yet stronger American marketplace which will further improve American companies who benefit from that marketplace.

6. VISION FOR THE FUTURE

The nationwide capacity must be created that can enable and sustain the production of world class FTA products that are reasonably priced and are responsive to consumer demands. The sustained capability must be systematically developed as part of a new comprehensive vision. The backbone for the vision will be an information infrastructure that interconnects the entire FTA industry and contains information that can amplify any one firm's efforts. The infrastructure will enable the industry to leverage its collective efforts for its common good.

The essential elements for the vision consist of:

- a clear identification of consumer needs;
- the physical network that will connect firms together;
- the internal computerization and networking within each firm;
- on-line information that can benefit each firm's activities;
- sources that will create and continuously_add to that information;
- the integration and technology to make beneficial use of the information available to each firm;
- automation that will increase productivity; and
- education and training so that the industry can avail itself of the new capabilities created.

With these elements in place, both the "bottom-up" approach of demand-activated manufacturing as well as the "top-down" approach of design-driven, multi-enterprise, concurrent engineering can be enabled. The rewards from both worlds can be realized.

The information infrastructure will enable new business structures to be developed and will allow them to coexist side-by-side with today's business structures.[15] It is not clear that the most efficient business structure for the FTA industry requires life cycle functions from design to production to sales to exist within one company. Small companies that specialize in design only, or in technical services (such as patternmaking) only, or in personal style consultations, etc., might demonstrate their ability to be healthy competitors and enduring entities. In fact, a whole new high-technology, cottage industry that is tied into the information infrastructure could emerge, consisting of many independents operating out of their homes, or out of very small companies [WIL91-1].

As mentioned previously, the average size of U.S. apparel manufacturing companies is just under 50 employees. An American apparel industry whose firms maintain their independence among themselves, but leverage their collective efforts, can produce world class products. The proximity to their market as well as their ability to focus on narrow market niches due to their small size can give these firms a competitive advantage over their foreign competitors.

An enterprise framework that represents the entire FTA industrial system (including retail) in functional terms can serve as a roadmap for building the new information

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[15]The idea of "Shared Teaching Factories" could be a foundation for these new business structures [LET91].

infrastructure. The enterprise framework can be used for establishing priorities and coordinating work to create the new infrastructure in an intelligent way. An excellent starting point for the enterprise framework is the Apparel Manufacturing Architecture (AMA) [JAY90]. The AMA specifies the functions required in a single apparel enterprise and the data flow relationships among these functions.

An extension of the AMA is necessary to accomplish the goals expressed here. First of all, the architecture must be extended beyond a single apparel manufacturing enterprise to include multiple enterprises in all sectors of the fiber/textile/apparel/retail industry. Secondly, the perspective must be taken that all the functions specified can be distributed across organizations whenever possible. This is an important key to permitting different business structures to coexist within the same architecture. For example, an apparel manufacturer might "out-source" all of its design work to an independent design cooperative. Out-sourcing design means moving the design function outside its normal position within a single apparel manufacturing enterprise. Innovative practices such as this example may serve an important role for the future FTA industry, and should not be discouraged by an enterprise framework that does not include their possibility.

Standards help create the information infrastructure, and furthermore, tie it together. Consensus for an enterprise framework for the FTA industry, along with consensus for a common terminology, are vital. Once an enterprise framework is recognized as a standard, interfaces among all functions associated with that framework can be identified and standardized as well. Such standards are known as open system standards, because they promote the development of alternative products for each of the functions. Each product may be unique, but they all have the characteristic that they are plug-compatible into the open system. Consequently, the entire system is enhanced, its capability leveraged by the efforts of many organizations, each competing for the customer's favor. Multiple market niches can be satisfied. Each customer, for example an apparel manufacturer, can put together a unique solution to its own particular situation from an array of products. In effect, the customer can put together a customized system from off-the-shelf components.

Among the most important standards needed are product data standards, in particular, the Standard for the Exchange of Product Model Data (STEP) [ISO00]. STEP is key for integrating the FTA product life cycle, because it enables the implementation of shared databases among all the functions in the life cycle.

A common terminology is essential. It is necessary not only for manufacturers to communicate electronically together, but also for manufacturers to communicate to suppliers, to communicate to retailers, etc. In addition to terminology to specify tangible parts, a terminology is necessary to specify skills, and collections of skills. Developing a standard terminology for skills is necessary to identify education and training goals, as well as to map various skills to each of the functions in the enterprise framework for the industry. Without a common terminology, any integrated effort will result in a "Tower of Babel."

Finally, networking standards are needed to tie the computerized systems together, to leverage their capabilities, and to access shared databases.

Information resources that can be accessed by the FTA industry are essential to amplify the industry's capabilities. The information will include databases for style data, anthropometric data, consumer profiles, materials data, etc. The material information will include data that describes the raw material, how that material was processed, its cost, and how to acquire that material. A skills database will also be very important. The skills database will be developed along organizational as well as individual lines, so that labor resources can be combined to manufacture products in new types of business structures [WIL92-3].

The information resources will be contained in distributed databases that the FTA industry can access. Certain organizations will develop the content for the databases. The same or other organizations will maintain the databases and distribute the information.

In the future, apparel firms will create new designs by intelligently using the information amassed, rather than beginning each new design from scratch and without regard to information that was previously not considered at all.

Upgrading America's FTA industry to produce world class products will require upgraded labor skills throughout the entire industry. In the same way that research and development efforts should not be fragmented, education and training must be diffused industry-wide as part of a comprehensive plan. Three categories of skills and knowledge are required: vocational skills for the production employees; technical skills for the professional staff; and business management skills for the managerial and executive staff. Educational programs in all three categories must be customized for the FTA industry.

The establishment of apparel design engineering as a new engineering discipline can help provide the unique and demanding educational background needed for success in the industry. The curriculum can draw from traditional engineering sciences, as well as from the arts. People educated in the new discipline will do the research demanded in the future and help build on that knowledge base and disseminate it to the industry as it is developed.

The enterprise framework that is agreed upon by the FTA industry can be used to help categorize, into separate job positions, the skills and knowledge required for the industry. The comprehensive designation of job titles, descriptions, and the skills and knowledge required for each job can provide a roadmap to employees for advancement. For example, a person may aspire to become an apparel design engineer or perhaps a textile manufacturing engineer. The skills and knowledge required for these types of positions might be acquired through intermediate positions where subsets of that knowledge could be obtained. Subsequently, an employee could enter the industry at an entry level production position and eventually advance to a professional position in a clear, progressive manner. The knowledge that advancement is possible, even from an entry level position, provides incentive for personal growth, not to mention incentive for choosing the industry as a profession in the first place.

Jobs in the apparel industry of the future will demand skills and knowledge that can be acquired in educational institutions as well as apprenticing in the industry itself (depending on the job). New education and training methods should be explored and developed. New educational materials, including software tools, should be developed. The entire enterprise framework should be studied, and educational resources should be matched to it to provide the skills needed throughout the FTA industry.

Employees in the future American FTA industry will be higher skilled, produce finer products, and as a result, command higher wages.

The research and development necessary to create the new information infrastructure, and continually nourish it with new knowledge, will be done at university, industry, and

independent laboratories across the country. A consortium of industry-wide organizations must work together to direct this research and development effort. The effort must be leveraged, rather than fragmented, to advance research goals as efficiently as possible and make them available to the entire industry. The leadership of the consortium should comprise individuals who are knowledgeable of the needs of the industry.

To help focus the effort required for creating the system-wide integration, a national laboratory for design engineering should be established. The laboratory will serve as technical liaison between the consortium leadership and all of the organizations that are accomplishing the work. In addition, the laboratory will provide technical coordination.

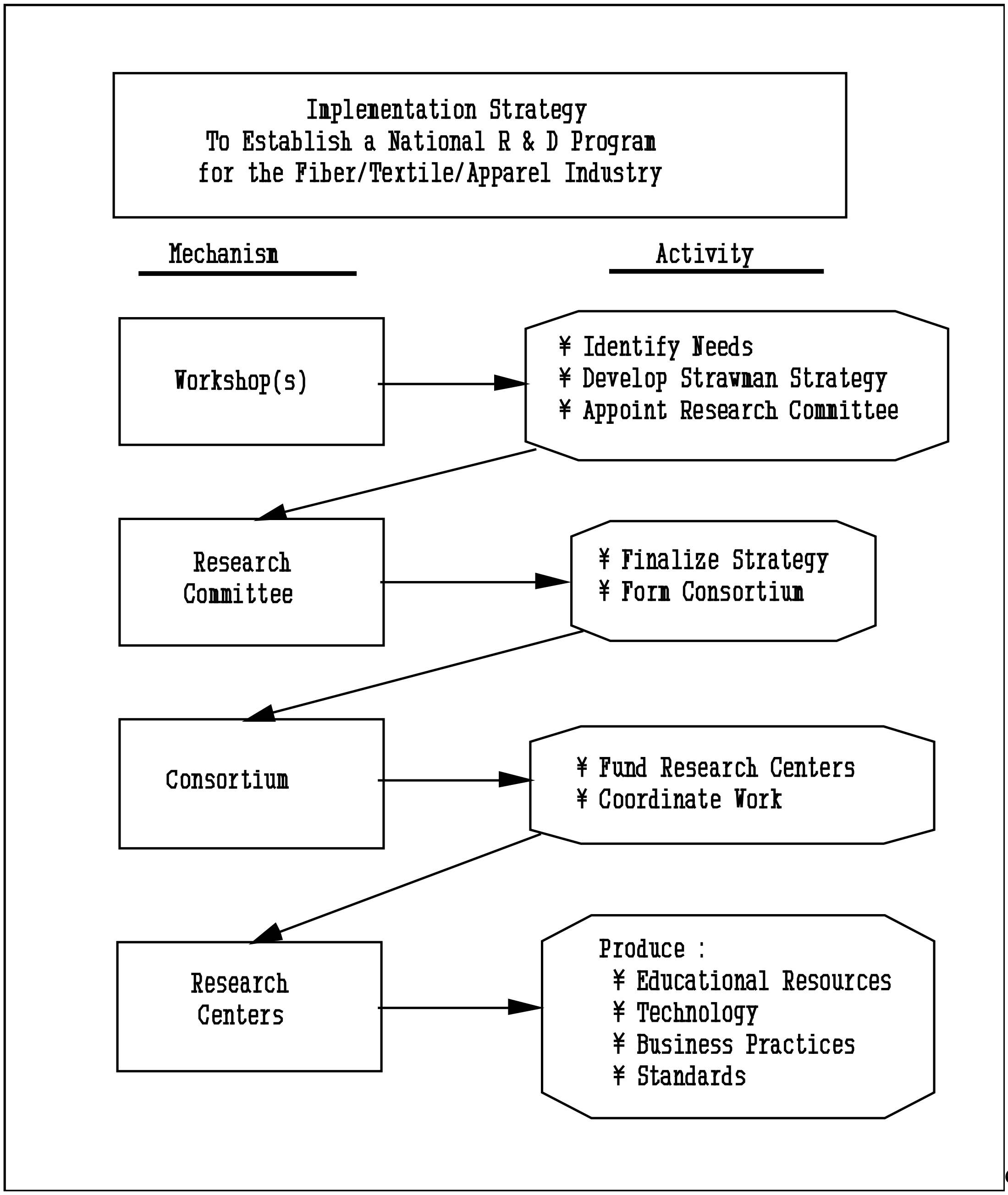
The laboratory should be charged with researching the issues involved concerning design engineering for the FTA industry. It will be a one-stop showcase for the newest technology; it will provide facilities and resources for outside researchers and staff to develop new technology related to FTA design engineering; and most importantly, it will coordinate efforts to develop international standards for FTA product data. The standards will play a key role in enabling design-driven engineering for the FTA industry, as well as enabling demand-activated manufacturing.

Funding for the entire research and development effort required will be large. Industry needs to form a consortium that can generate the funding required to establish the new information infrastructure. Equally important is the leadership role the government can play in advancing the vision proposed in this paper. The payoff will be the strengthening of the American FTA industry to maintain it as the foremost in the world.

7. IMPLEMENTATION STRATEGY

The following figure presents an implementation strategy to establish a nationwide research program to support the new FTA industry.

A kick-off workshop should be held to clearly identify the needs of the industry. The participants will include FTA industry leaders and government leaders. The first goal of the workshop will be to clearly delineate needs to which the industry will respond, and to delineate clearly both short-term and long-term goals. Based on these determinations, a



document will be drafted that defines a strategy for establishing a nationwide research program in behalf of the FTA industry.

One or more workshops may be held to obtain additional input from technology experts in the

FTA and related industries. A third goal of the workshop(s) will be to designate members for a newly formed research committee.

The research committee will finalize the national research strategy, and develop strategies for establishing a consortium of industry participants.

The consortium will direct the nationwide research program and obtain funding to support the program in a unified industry effort. The funding will be directed to the newly established research centers around the country, including the national center, as well as the already existing research centers. The technical work will be coordinated by the consortium and directed through the national center.

Once organized and funded, the research centers will serve as a source for information and educational resources, develop new technology, develop new business practices, and produce standards. The centers will ensure that the reservoir of new technology will be continually replenished. The organizational structure of the nationwide effort will ensure that the new technology is efficiently transferred to industry and put to use. The organizational structure is described in the next section.

8. ORGANIZATIONAL ROLES

A nationwide effort is necessary to establish the new, information technology-based FTA industry. Ultimately, people and organizations from all aspects of the industry, as well as related fields, will be involved in creating the new FTA industry and in benefiting from it. Industry organizations will include apparel manufacturers, textile manufacturers, fiber manufacturers, retailers, FTA CAD/CAM vendors[16], apparel and textile experts, and apparel consulting companies. Academia will include people from fields such as apparel, textiles, material science, engineering design, computer science, and the arts. Government will include national laboratories and agencies associated with commerce, procurement, education, and military logistics. Other organizations will include companies with peripheral interest in the FTA industry (e.g. upholstery companies), standards organizations, and professional and trade associations.

All of the organizations mentioned above will be part of the new FTA industrial system

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[16]FTA CAD/CAM vendors are companies that develop and market computer-aided design (CAD) and computer-aided manufacturing (CAM) software packages for the FTA industry.

and will serve its functional requirements. Functional requirements include administrative management, technical management, information management and disbursement, information development, research and development, standards development, testing and validation, education and training, and funding.

A summary of the probable roles played by contributing organizations is presented in Tables 1 and 2. The roles shown in the tables are limited to the issues discussed in this paper. A complete description of the role for a particular type of organization is not given. The tables are intended to give the reader a general idea of the effort required and the distribution of potential benefits.

Table 1 shows the effort required for each type of organization. Organization types are listed down the left column. The type of effort required for each type of organization is divided into four categories, listed across the top row of the table. The category "Education & Training" refers to that provided by each type of organization to provide for its own needs or for the needs of the entire FTA industry. The category "New Technology" refers to the new information infrastructure, its related technologies, and other technologies that improve design and manufacturing productivity. The category "Business Practices" refers to business practices for the FTA industry organizations. An entry is listed for each organization type that describes how it will contribute to improving business practices for the FTA industry relevant to the new technology. Finally, the category "Standards" is mainly concerned with product data standards that provide interfaces between processes in the FTA product life cycle.

Table 2 shows the benefits each type of organization derives. The table can be interpreted in a similar manner as Table 1. One row has been added to the bottom of the table for the organization type "Consumer." The consumer will realize real benefits, and these are summarized in the table. The benefits derived from each category of effort should be interpreted as that derived as a consequence of that effort. For the category "New Technology," the interpretation is extended to include the benefits deriving from participating in the national collaboration of effort. The category "Business Practices" refers to benefits deriving to each organization type because of new business practices that will be adopted by the new FTA industry. Finally, the category "Standards" refers to the benefits derived from the use of standards.

Table 1: Effort Required to Establish a New, Information Technology-Based FTA Industry

	Education & Training	New Technology	Business Practices	Standards
FTA Industry	Develop in-house training for needs and identify skill requirements	Integrate product life cycle into new information infrastructure	Structure business for design-driven engineering & demand-activated manufacturing	Cooperate on development and use of standards
Professional Societies	Develop, accredit, & approve courses & curriculums relevant to FTA industry	Distribute information through papers and journals	Assist in inter-firm and inter-industry information needs	Coordinate, develop, and review standards
Management & Technical Consultants	Advise on relevant training for individual firms	Advise on best technology for individual firms	Advise on how to utilize design-driven engineering & demand-activated manufacturing	Advise individual firms on benefits & use of standards
Equipment & CAD Vendors	Train customers in use of equipment & software that utilizes new technologies & standards	Utilize in new product developments	Develop open architecture products that are compatible with the enterprise framework	Cooperate on development of standards & implement them in products
Academia	Add courses related to new technology to the curriculum; expand vocational training	Conduct R&D in new technologies	Provide information on new technologies to the information infrastructure	Include standards relevant to the FTA industry as part of instruction & R&D
Research Laboratories	Provide information on new technologies	Conduct R&D in new technologies	Provide information on new technologies to the information infrastructure	Research and test standards in prototypes
National Laboratory	Provide information on product data standards, multi-enterprise, concurrent engineering, & design engineering	Coordinate research efforts in design engineering and provide resources for in-house R&D	Provide information on new technologies & standards to the information infrastructure	Coordinate development of product data standards and serve as test bed for them

Consortium	Fund & direct development of educational and training resources	Fund & direct consortium sponsored R&D	Recommend new business practices to take advantage of new information infrastructure	Fund standards development and recommend their use
Government Agencies	Provide incentives to establish new educational facilities to support the FTA industry	Work with consortium & support development of information infrastructure	Encourage adoption of new business practices to take advantage of new information infrastructure	Support standards development and encourage their use

Table 2: Benefits Derived from an Information Technology-Based FTA Industry

	Education & Training	**New Technology**	**Business Practices**	**Standards**
FTA Industry	Obtain higher skilled and more efficient employees	Leverage nationwide effort of FTA industry via information infrastructure	Neutralize foreign advantage of low labor cost and compete in style and quality	Custom configure design and production system from off-the-shelf components
Professional Societies	Gain prestige by adding highly skilled engineers	Build breadth and depth in resources for new technology	Reduce information redundancies via linkages between industries	Leverage work on standards between industries
Management & Technical Consultants	Learn about the best training programs from the entire FTA industry	Match new technologies to unique needs	Learn about business improvements resulting from new technologies	Learn about the use of standards to improve the bottom line
Equipment & CAD Vendors	Expand markets to customers with higher skilled labor force	Have access to large pool of pre-competitive technology	Learn needs of FTA design & production engineers	Expand markets to customers "locked" into competitors' products
Academia	Receive direction on subject matter that is relevant to industry; have access to industry laboratories	Leverage research efforts	Have access to hands-on-training methods in design & production engineering	Reduce quantity of information required
Research Laboratories	Obtain higher quality engineers	Leverage research efforts	Discover industry links for new technology	Discover different techniques for developing standards
National Laboratory	Gain credibility via access to practical, industry information	Avoid redundant research efforts	Have access to better business information	Enjoy clearer communications with all sectors of FTA industry
Consortium	Enhance sharing and understanding in industry policy decisions	Realize greater value for research dollars; avoid redundant research efforts	Impact entire industry—increased ability to achieve overall goals	Enjoy clearer communications with all sectors of FTA industry

Government Agencies	Enhance sharing and understanding in industry policy decisions	Obtain quality, made to measure products at lower prices	Specify requirements electronically; reduce inventories; implement CALS objectives[17]	Specify products required unambiguously
Consumers	Gain appreciation of quality products; influence market offerings by better expressing needs	Obtain quality, made-to-measure products at lower prices	Have access to alternative shopping methods	Obtain consistent quality products

[17]The government supports the DoD Computer-aided Acquisition and Logistic Support (CALS) program as a major initiative to produce a paperless system for government transactions, both on the business and technical sides. STEP is seen as the principal vehicle for accomplishing this on the technical side. A natural fallout to realizing the vision described in this document will be advancement of the CALS goals through STEP development.

9. SUMMARY AND CONCLUSIONS

• A successful FTA industry is critical to the well-being of the American economy.

• Each sector of the FTA industry is the most productive in the world. Nevertheless, the industry is in serious danger due to imports.

• The FTA industry is not viewed as a "sunset" industry by Western Europe or Japan. It should not be viewed that way by the U.S. However, government support for research and development for the FTA industry has been low.

• To compete effectively, the FTA industry must be converted from labor intensive to intelligence intensive. The apparel sector is currently the most labor intensive of the three industry sectors and requires special attention.

• Information technology can be the linchpin for unifying the research and development necessary to convert the industry from labor to intelligence-intensive enterprise activities. Any enterprise activity that uses and/or provides information, including CAD systems as well as automated equipment installed in the factory, requires information technology to obtain maximum benefit.

• The information technology enablers include an enterprise framework, product data standards, and design engineering. An information infrastructure must be built to incorporate these elements.

• The information infrastructure will enable bottom-up, demand-activated manufacturing to be developed, as well as top-down, design-driven, multi-enterprise, concurrent engineering.

• Improved design tools and practices, integrated into the product life cycle from design through manufacture, will be particularly effective in converting the apparel sector, notably the high fashion segment of it, from labor to intelligence intensive.

• Consumer needs and desires should be taken very seriously, and methods should be developed to incorporate those needs and desires directly into the information infrastructure.

• The ability to leverage information, utilize improved design tools, and provide for new types of business structures within the industry can enable the large number of very small apparel companies to be a strength, rather than a liability.

• The creation of a new discipline "apparel design engineering" can be a catalyst to unify the efforts mentioned above that are related to the apparel sector.

• A national laboratory devoted to design engineering would be useful to help focus the effort required to develop the information infrastructure and fully integrate the design process into it.

• Finally, to effectively utilize the new technologies, education and training must be provided throughout the industry by educational institutions, as well as by the industry itself. Subsequently, the average wages in the industry can be expected to rise, as the better trained employees are more productive and produce higher quality products.

This paper provides a strawman plan by which the FTA industry can move toward the use of 21st century information technologies in a unified, rather than a fragmented and redundant, manner. A unified, national strategy is necessary to enable the industry to have a stronger voice in obtaining the support that it needs, and subsequently to develop the concerted effort to succeed. All facets of the industry must be represented, because all have a role to play in strengthening it.

The first step needed to develop a national strategy is to convene a workshop of FTA industry leaders to discuss the industry needs and determine a strategy for applying information technology to answer those needs. The workshop would be focused on information technology, not only because of the importance of that technology relevant to industry needs, but also because information technology is the unifying linchpin that can tie together all of the research and development effort that is needed. The main output from the meeting would be a draft document for a unified, national strategy to strengthen the technical foundations of the FTA industry.

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B NIST INVOLVEMENT IN THE APPAREL INDUSTRY

The National Institute of Standards and Technology (NIST) was encouraged by the Defense Logistics Agency (DLA) to begin working with the apparel industry because of NIST's experience in product data standards, in particular the Standard for the Exchange of Product Model Data (STEP). STEP is an emerging international standard[19] for representing the physical and functional characteristics of a product throughout a product's life cycle. As a standard, STEP will permit communications among computer environments, each of which performs various product life cycle functions. The principal technique for integrating the various systems and exchanging data will be a shared database.

Many of the information requirements as well as the software tools being developed to support STEP are applicable for any manufacturing industry. To serve the needs for a particular industry, Application Protocols (APs) are developed that designate the specific information and application requirements for that industry [PAL91].

In recent years, NIST has been working on a project to develop STEP APs to support computer integration of the apparel product life cycle. The project is sponsored by the Defense Logistics Agency (DLA), and the work is being carried out in cooperation with the Computer Integrated Manufacturing Committee of the American Apparel Manufacturers Association (AAMA). The project has been named the APDES project to stand for the Apparel Product Data Exchange Standard.

The APDES project is part of a substantial program sponsored by DLA to improve apparel manufacturing technology. The DLA program is advancing technology from traditional size-based methods (ready-to-wear) to methods that use body measurement data directly (made-to-measure). Additionally, the program is advancing production methods from fixed procedures based on standard products to flexible, computer-integrated manufacturing using product representation standards to communicate requirements. The new technologies developed will lead to better fit, higher product quality, economical unit-production methods, and quick response. All told, the program is a broad evolution toward integrated enterprises, in which all phases of a product's life cycle are coordinated through a framework of

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[19] Refer to ISO 10303-1, *Industrial Automation Systems and Integration-Product Data Representation and Exchange-Overview and Fundamental Principles*, to be published.

standards, concurrent engineering practice, and supporting technology.[20]

The goal for the APDES project is to develop manufacturing data standards based on STEP that will support integration of the projects that DLA is sponsoring. The first objective, when the APDES project began, was to demonstrate the feasibility of using STEP for apparel. The objective was accomplished by developing an information model for pattern data using STEP technology [LEE90]. The information model was represented in the EXPRESS modeling language [ISO91]. The model was implemented in a computer program that exchanges pattern data between two proprietary industry formats [MON91]. A neutral set of data structures, based on the information model developed, was used as the intermediary in this process. It was concluded that STEP APs can provide the information interfaces to integrate the apparel product life cycle. In recent work, a set of APs was specified for the manufacturing data interfaces of an apparel manufacturing enterprise [MON00]. The selection and scope of the APs determined were based on the Apparel Manufacturing Architecture (AMA) developed at the Georgia Institute of Technology under DLA sponsorship [JAY90]. Currently, NIST is working with the AAMA to develop STEP APs that have broad industry consensus [LEE92]. The APs that NIST has been developing for the APDES project will be used as strawman APs in the broader industry effort.

During the course of the APDES project, NIST has had many interactions with individuals and organizations throughout the FTA industry. The organizations included universities, laboratories, trade organizations, companies, and government agencies. Furthermore, NIST attended many FTA industry meetings, workshops, and conferences, and gave presentations at a number of them, including the recent Computer Integrated Apparel Design Symposium.[21] The ideas for the vision presented in this paper were formed on the basis of all these interactions.

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[20]See footnote 11, page 8.

[21]The U.S. Army Natick Research, Development, and Engineering Center invited NIST to give a presentation at the Computer integrated Apparel Design Symposium in Boston, Mass. on June 29, 1992. The title of the presentation given by NIST was, "National R & D Collaboration for the Apparel/Textile Industry."

C DEFINITIONS AND ACRONYMS

This appendix contains definitions and acronyms that were used in this paper. Each term (or phrase) is listed in **boldface**, and its definition is given on the following lines. If a term has an acronym, that acronym is included within parentheses after the term. Additionally, the acronym is listed as a separate entry and references the term to which it refers. If the term that the acronym represents is self-explanatory, the term is not defined in a separate entry. For consistency, definitions for all terms begin with a phrase. If additional information is required, the beginning phrase is ended by a period and the additional information is added as complete sentences.

AMA
Acronym for Apparel Manufacturing Architecture

apparel design engineering
Engineering design of apparel products

Apparel Manufacturing Architecture (AMA)
Enterprise framework for an apparel manufacturing enterprise [JAY90]

apparel on demand
Demand-activated manufacturing of apparel products

CAD
Acronym for computer-aided design

CAM
Acronym for computer-aided manufacturing

capital intensive
Refers to a manufacturing process that employs capital equipment to achieve its productivity

commodity market
Market characterized by low quality, low cost products; produced by low-cost labor, or else automated mass production. The key determinants for success in the commodity market are based on producing apparel products as quickly and inexpensively as possible.

concurrent design

"Engineering design practice that combines the concerns of marketing, functional product and process design, production, field service, recycling, and disposal into one integrated procedure" [NRC91]

concurrent engineering
"A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements" [WIN88].

demand-activated manufacturing
Manufacturing system set up so that goods are pulled through the apparel pipeline (assuming apparel products) from fiber to finished product based on customer demand. This is the opposite of the current practice of goods pushed through the apparel pipeline based on manufacturers' anticipation of customer demand.

design-driven engineering
Similar to concurrent design, but emphasizes the aspect that tradeoffs arising from conflicting requirements of different life cycle processes are determined during the design process

deskilled
"Term that refers to simple tasks or jobs, which, as a result of work simplification or other reasons, require little or no skill to perform. Also said of persons who perform such tasks or jobs" [BAN81]

EDI
Acronym for Electronic Data Interchange

Electronic Data Interchange (EDI)
"The computer-to-computer exchange of structured business data, such as invoices and purchase orders" [MAR91]

engineering design
"The technical element in the product realization process that involves the application of knowledge and techniques from engineering, science, aesthetics, economics, and psychology in establishing specifications for products and their associated production processes; the technical process by which engineering descriptions and specifications are formulated to ensure that a product will possess the desired behavior, performance, quality, and cost"

[NRC91]

enterprise framework
Specification of the functions required in a single, manufacturing business and the data flow relationships among these functions

fabricated products
Products produced from textiles with value-added operations, particularly assembly. Apparel products are a subset of fabricated textile products. The entire vertical industry can be referred to as the fiber/textile/fabricated products industry.

fashion market
Market characterized by high quality, excellent fit, and high style apparel products; produced by high-priced labor, or else automated, flexible manufacturing–currently under development. The key determinants for success in the fashion market are based on producing apparel products with high quality, excellent fit, and especially, quick response to style changes.

FTA
Acronym for fiber/textile/apparel industry

information infrastructure
A network of information, stored on computer, that can be accessed by firms nationwide to leverage their capabilities. The information infrastructure will consist of the physical network that will connect firms together, the internal computerization and networking within each firm, on-line information databases, sources that will create and continuously_add to that information, and the integration and technology to make beneficial use of the information.

information technology
"The acquisition, processing, storage and dissemination of vocal, pictorial, textual and numerical information by a microelectronics-based combination of computing, telecommunications and video. Information technology has arisen as a separate technology by the convergence of computing, telecommunications and video techniques, computing providing the capability for processing and storing information, telecommunications providing the vehicle for communicating it and video providing high-quality display of images. This convergence has been catalyzed by the availability of complex, reliable and cost-effective microelectronic components and equipment. Global developments in electronics have also stimulated the search for common international standards, particularly in computing and telecommunications, which are paving the way for wide-scale applications of information

technology" [LON89].

intelligence intensive
Refers to a manufacturing process that employs a system and/or equipment that has intelligence incorporated into it to achieve its productivity

labor intensive
Refers to a manufacturing process that employs human labor to achieve its productivity

leverage
To obtain an increased return on an investment of effort by tying that effort together with other efforts or the results of other efforts; also refers to the increased return that an investment of effort has on other efforts

made-to-measure
An apparel product designed to fit a particular individual. The number of measurements used are more extensive than the one or two used for a ready-to-wear apparel product, and should generally produce a better fit.

multi-enterprise, concurrent engineering
Extends the concept of "concurrent engineering" from the optimization of a design and production system to the broader optimization of an industrial system. "It is the optimization of all the enterprise's operations, including planning, marketing, and financial operations, as well as its transactions with its suppliers, distributors, and other business partners" [CAR91].

PDES
Acronym for Product Data Exchange using STEP

Product Data Exchange using STEP (PDES)
The U.S. effort undertaken to support and accelerate STEP's objectives, and to ensure that the requirements of U.S. industry are incorporated into STEP

product data standards
Specifications of the information requirements for a product throughout the product's life cycle; enables the implementation of shared databases among all the functions in the product life cycle

product life cycle
Includes all processes in the life of a product "from conception through disposal, including

quality, cost, schedule, and user requirements" [WIN88]

QR
Acronym for Quick Response

Quick Response (QR)
"A strategy to reduce the time needed to get from raw material to point-of-sale in a retail outlet and to reduce the amount of inventory in the [retail/warehousing/manufacturing] pipeline" [WEI92]

ready-to-wear
An apparel product designed to fit a target population, not a particular individual. Its size designation is based on one or two dimensions. Though designed for a particular set of proportions, it is expected to meet the fit requirements for a range of differently proportioned individuals that can be approximately characterized by the size designation. Other sized garments of roughly the same proportions are designed by scaling (grading) the initial designed garment.

shared teaching factory
Factory which contains manufacturing equipment that can be leased to small companies and/or individuals who would not need full time use of the equipment and could not afford to buy or lease it for only part time use. Additionally, the factory provides technical and financial expertise to the entrepreneurs it supports to improve the probability for success. In other words, the cost of capital equipment, as well as expert advice, normally affordable to only a large company, is distributed over a number of small companies so that they can take advantage of similar opportunities that a high volume revenue base provides.

SIC
Acronym for Standard Industry Classification

Standard for the Exchange of Product Model Data (STEP)
An emerging international standard[22] for representing the physical and functional characteristics of a product throughout the product's life cycle. As a standard, STEP will permit communications among computer environments, each of which performs various product life cycle functions. The principal technique for integrating these systems and

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[22] See footnote 18, page 24.

exchanging data will be a shared database.

Many of the information requirements as well as the software tools being developed to support STEP are applicable for any manufacturing industry. To serve the needs for a particular industry, Application Protocols (APs) are developed that designate the specific information and application requirements for that industry.

Standard Industry Classification
Classification for manufacturing industries by industry definitions described in the Standard Industrial Classification Manual [OMB87]

STEP
Acronym for Standard for the Exchange of Product Model Data

sunset industry
An industry that is characterized by low technology and, consequently, labor-intensive operations. Such an industry should be allowed to fade away "into the sunset" by a developed country. However, the FTA industry is being converted to a capital-intensive industry, employing sophistocated technology; it should not be characterized as a sunset industry.

world class apparel products
High-quality apparel products that are designed for the entire apparel product life cycle. In other words, not only function and style, but also manufacturability as well as other life cycle concerns, must be designed directly into the product.

D LIST OF ORGANIZATIONS

This appendix lists the organizations that are referenced in this paper, the acronym for each organization in parentheses, and a brief description of the mission of each organization.[23]

American Apparel Manufacturers Association (AAMA)
Improve the competitiveness of American apparel manufacturers through collaborative efforts–includes research, education and training, and business practices

Defense Logistics Agency (DLA)
Provide for the logistics support (food, clothing, shelter) of the military services

Fabric and Suppliers Linkage Council (FASLINC)
Develop voluntary standards and protocols for transactions between members

Factory Automation Systems Division (FASD) at NIST
Apply information technology to improve the technology base of American manufacturing

International Textile and Apparel Association (ITAA)
Exchange ideas in the research and teaching of apparel design

National Institute of Standards and Technology (NIST)
Improve the technology base of American industry through the development and transfer of technology to industry and through the development of standards

National Textile Center (NTC)
Support university research of the FTA industry

Sundries and Apparel Findings Linkage Council (SAFLINC)
Optimize the forecasting aspect of interface with customers and to develop optimum methods for handling large numbers of small items such as buttons

Textile-Apparel Linkage Council (TALC)
Develop voluntary standards and to promulgate and encourage the use of standards through seminars, meetings, and publications

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[23]Some of the information on this page was provided by Tom Malone at the Department of Energy (DOE) Critical Technologies Workshop, Berkeley, CA, May 28-29, 1992.

Textile/Clothing Technology Corporation ([TC]^2)
To expedite the automation of the labor-intensive apparel industry

Voluntary Inter-industry Communications Standards Committee (VICS)
Provide leadership in the use of standards for the capture and transmission of product related information between manufacturers and retailers