1 Introduction

This report on the Demand Activated Manufacturing Architecture Project (DAMA) is the result of a seven-year research project funded by the Department of Energy (DOE) through the American Textile Partnership (AMTEX). The DAMA Project has developed an inter-enterprise architecture and analysis methodology for supply chains that will enable improved collaborative business across the supply chain. The industry has determined that collaborative business practices are necessary to provide a significant reduction in time and cost to product supply chains. The opportunity for savings in the U.S. softgoods industry is estimated at $45 billion per year with a realistically achievable 50% reduction in time.

The DAMA Project vision was stated as: By the year 2000, the DAMA Project will have identified and demonstrated means for the U.S. softgoods industry to improve responsiveness to the consumer that can result in a 50% reduction in time in the pipeline.

The Department of Energy has determined that there is a need to ensure a reliable nuclear deterrent with declining resources by applying information technologies and collaborative business practices. The DOE goal is to reduce new product realization cycle time by 50%, which will result in significant cost savings, while achieving ten times fewer defects.

The DAMA Project addressed the needs of the softgoods Industry and DOE through the goals, steps and activities of the project during the execution of the work. DAMA research throughout the project included a number of studies, development efforts and pilots, each of which will be discussed in this document. A synopsis of accomplishments resulting from the DAMA work can be summarized as follows:

1. Assisted industry in becoming sufficiently knowledgeable to take advantage of Internet communication and security technologies.
2. Developed and made available for commercialization a number of technologies (See Section 8).
3. Completed an inter-enterprise architecture for softgoods supply chain collaboration.
4. Developed a guide for supply chain collaboration.
5. Introduced modeling and simulation to the softgoods industry to analyze supply chain configurations.
6. Results were transferred to key industry standards associations.

In order to accomplish DAMA's vision industry needed to become more focused on consumers by developing a supply chain management process that would be demand driven. To accomplish the vision meant supply had to be synchronized with demand. Production had to be synchronized to replenish product at the consumer's pull rate. In 1994, the Project started by characterizing the supply chain. Then, focus groups with representation from all four sectors of the U.S. Softgoods Industry and the national laboratories further defined the primary needs for the project based on their vision for the future. The projected needs included:

- Collaborating across the entire supply chain
- Improving communications and secure data exchanges
- Making cooperative business decisions (multiple companies in a supply chain)
- Reducing the time and inventory in the supply chain
- Identifying cultural issues across the supply chain

This set the stage for DAMA to develop the tools and methodology that would support collaborating and exchanging data across the entire supply chain. It also meant developing an information system infrastructure for sharing information selectively and securely across the supply chain. The Internet was chosen as the vehicle for information
However, from the beginning, there was an issue on whether the softgoods industry was ready to collaborate. The industry's readiness was tacitly assumed, because of their apparent enthusiasm at the project's inception. In fact, however, there was systemic resistance to the notion of collaboration because of the industry's competitive and adversarial business culture. This resistance is not unique to the textile industry.

2 Supply Chain Analysis
One of the primary mechanisms used to understand the entire supply chain was product line investigations. In an effort to elucidate specific value-chain and market segment characteristics of the U.S. Softgoods Industry, four products were chosen for investigation. The Enterprise Modeling and Simulation (EM&S) Team, led by Lawrence Berkeley National Laboratory (LBNL), was commissioned to the task of examining, tracking and documenting the production of these specific textile products from fiber production to the retailer's display of finished goods. The products chosen for the investigation and data collection were:

- A pair of men's wrinkle-free cotton slacks,
- A men's nylon Supplex® parka,
- A single flat white poly-cotton blend bedsheet, and
- A ladies' wool fashion blazer.

The investigations focused on the companies involved in the business processes and the relationships between them, the events that triggered the business processes, and the data and information flow generated by the business processes. The approach was to form a team of the participating companies and members of LBNL and visit the locations in the supply chain where activities occurred relating to the chosen product. The investigation team viewed the operation and interviewed key personnel and recorded the process steps for each product supply chain.

From the product investigations, process step maps were developed for each of the four product pipelines, which included the fiber, textile, sewn products, and retail business processes. The process step diagrams displayed the activities necessary for the production of a product and serve as a tool for understanding where opportunities for improvement lie (See Figure 1).

![Figure 1. Process Steps for Men's Cotton Slacks](image_url)

The results of these pipeline investigations confirmed the need for new tools and processes that address inter-enterprise supply chain management and coordination. Management at this scale and complexity cannot be accomplished through the use of company-focused decision support tools that are necessarily limited in scope. Studies conducted under the EM&S task revealed that inter-enterprise focused tools, also called cooperative business management tools, are needed to achieve true synchronization of the myriad manufacturing, transportation, and business processes needed to manufacture softgoods and move them through the supply chain to the consumer.
Another result of the pipeline analysis work was the discovery that computer-based tools alone will not eliminate softgoods pipeline problems. To achieve the goals of DAMA, business practices also have to change. A task was formed to understand linkages between business practices and data, generate a common business model and the supporting data definitions required to make collaborative decisions. The models contain business processes and information from the viewpoint of retail, apparel, textile, and fiber manufacturers and consist of text and graphical descriptions. Continued industry collaborations with American Apparel and Footwear Association (AAFA), American Textile Manufacturers Institute (ATMI), and Voluntary Inter-industry Commerce Standards (VICS) helped ensure that the models accurately captured the business processes used in the industry. The models were completed and are available from [TC]2. They are:

1. The Quick Response Apparel Business Model,
2. Textile Industry Supply Chain Business Model, and
3. Logistics Process Map for Assembly in Mexico.

There was also an effort to understand the roles and issues of small and medium size enterprises (SMEs) in the softgoods industry. A survey and series of visits revealed that EDI, sourcing and communications were the critical issues (see Section 3.2).

From the beginning of the supply chain research, the DAMA Project participants believed that tools and techniques were needed to demonstrate the effects, risks and benefits of changes to the softgoods supply chain. In every case, the proposed changes affected the business processes and the business relationships between companies. A technology familiar to the national labs was computer simulation. With simulation techniques, complex problems, systems and multiple relationships can be mimicked and tested to see how the system performs. Over the duration of the Project, there were several models developed that simulated parts of the softgoods supply chain. These models became learning lessons for the Project teams and evolved the thinking to arrive at an optimal solution for the supply chain collaborative model.

The DAMA Project proposed that cooperative business management or what is now called collaboration could help to synchronize the business processes and shorten some of the lead-time. It was also understood that a secure information infrastructure was needed to support the new collaborative business practices. To demonstrate that collaboration would work, the DAMA Communications and Infrastructure team developed a secure infrastructure tool, called TEXNET to share data across the Internet (see Figure 2). In 1995, there were no commercially packaged solutions to do this and most companies were not convinced that collaboration would work.

A series of DAMA pilots with participating companies demonstrated that the key concepts were valid. There were several EDI on the Internet pilots showing that data could be shared in an easy economical way. In the succeeding TEXNET pilots, forecasting, shipping and inventory information was shared with successful results (see Section 6). True collaboration is more than just sharing data. It means making decisions jointly to increase the performance of the supply chain instead of each company's performance.
3 DAMA Supply Chain Architecture

The softgoods supply chain consists of a number of companies, which take a supplied material (e.g. cotton, or fiber) and convert it from the raw or semi-finished state to a state of completion and greater value. These supply chain activities result in the production of a consumer product, sold through retail.

Through the work of the DAMA project, an inter-enterprise architecture has emerged. It was recognized that technology driven solutions were difficult to implement. Developing a solution for Demand Activated Manufacturing required more than a software program. Developing technology is relatively easy; developing technology that is used successfully is much more difficult. The most successful technical solutions must be business driven. The analysis of that concept led to a five-component architecture.

DAMA's Inter-Enterprise Architecture (which spans multiple companies across a supply chain) is shown in Figure 3. Each company (enterprise) in a sector may have their own unique internal architecture for sharing corporate information. The key architecture for collaboration across the supply chain is the support of a common set of information available to all members of the supply chain. The information must be timely, accurate and secure.
The DAMA project has identified four distinct sectors (or tiers) of distributors and suppliers in the softgoods supply chain: retail, apparel, textile, and fiber. N-Tier is a term used to describe a supply chain with multiple tiers of suppliers.

DAMA's early focus for developing an architecture to support demand activated manufacturing was technology-driven. In 1997, the DAMA leadership changed the focus to pursuing a top down or business-driven approach. This business-driven approach stressed the importance of understanding three fundamental concepts before the move to collaboration can be made:

- Knowledge of industry culture and business practices,
- Development of process maps of industry models of information flow,
- Construction of collaboration frameworks for business practices.

Once the companies desiring to collaborate within a supply chain understand these requirements, then the deployment of architecture-based information systems for collaboration to support new ways of doing business can begin.

The activities described in the DAMA N-Tier Collaboration Model provide the logic for the Collaborative Industry Supply Chain Simulation (CISS) model. This model illustrates how a single demand plan is made visible to all members of the chain. It also shows how that information would be processed and shared with each company participating in the collaboration, as well as how the identification of exceptions and resulting collaboration to resolve those exceptions will occur.
Although the DAMA Architecture was developed based on sound concepts, it required validation to support the perceived benefits. In this effort, simulation models were developed to compare the performance of proposed collaborative supply chain solutions with the traditional supply chain operations. The measure of success is shown as improvements in lead-time and inventory levels.

In order to validate the DAMA Architecture, multiple models were required to handle the various supply networks and business processes. The first of the models developed focused on accurately modeling the current supply chain and calculating lead times for the various partners in the supply chain. Subsequent models built on this framework and added functionality to support the DAMA Architecture that included the logic for collaboration between the supply chain partners. It resulted in a dramatic decrease in lead-time because it eliminated duplication of effort in many administrative departments and synchronized the flow of information. Once these models were developed, logic was added to determine inventory levels for each of the partners. The resulting two models include the lead-time calculations, as well as, the inventory levels at each stage of the supply chain.

The results from the simulation models proved that the DAMA Architecture did, in fact, have a positive impact on order lead-time and inventory among the partners. The two lead times that were calculated for each Partner were the planning/production lead-time and the order lead-time. The planning/production lead-time is defined as the time when a forecast enters Demand Planning until a completed production order is sent to the Finished Goods Warehouse. The order lead-time is defined as the time from order receipt until it is delivered to customers. Model results are shown below and illustrated in Figure 5 and Figure 6:

- Across all partners in the collaborative supply chain model (CISS), there was a reduction of 16 days in the order lead-time versus the traditional supply chain model (TISS), which is a 49% decrease. Also, the collaborative model reduced 137 days from the planning / production cycle which represents a 49% decrease in time in the supply chain.
- For each partner, in the collaborative model (CISS), there was a reduction in finished goods inventory from just over
6 weeks worth of units to approximately 2.5 weeks of inventory while providing the same level of customer service.

**Figure 5. Lead Time Model Summary**

**Figure 6. Inventory Model Summary Results**

### 4 Conclusions and Observations

One conclusion the DAMA Project reached as a result of building these business process models and the interactions with industry experts is that the long lead times were caused by three major factors:

- The inability to accurately forecast what the consumer would buy 6-12 months in the future,
- The number and complexity of the process steps in the pipeline, and
- The lack of synchronization among the supply chain partners.

Before the DAMA model for supply chain collaboration can occur, the participating companies must champion and implement a new internal business paradigm. Roles and organizational relationships must change. In addition, performance metrics need to change as roles change.

A number of important lessons were learned during DAMA. These lessons are not new in concept, but continue to arise in the research. And, even though the issues involved are understood conceptually, that does not imply they can be satisfactorily resolved in a short period of time. The lack of trust is a significant deterrent and is a universal problem. When companies do not trust one another, collaboration attempts fail. As a prerequisite, collaboration requires sharing more proprietary data than is currently shared.
Another lesson learned was technology promotes change. Today, technology is not a showstopper for collaboration since there are many proprietary and commercial technologies available to support changes. With this new technology, an array of new business opportunities exists to support the change to collaboration and other new business paradigms.

The DAMA Project concluded that demand activated manufacturing is the right answer. Demand activated manufacturing focuses on consumer demand throughout the supply chain and requires collaborative supply chain management. There are successful industry standard examples like Collaborative Planning, Forecasting, and Replenishment developed by the Voluntary Inter-industry Commerce Standards (VICS) group.

Collaboration is implemented in three phases. The first phase is the preparation phase where business agreements define the scope, goals and roles of the supply chain partners. The second phase is the piloting phase where a small number of companies test the partnership procedures and technology to see if goals can be achieved. Then, when successful, the pilot is scaled up to the agreed upon operational level. Each phase should be accomplished in sequence. The entire process may take several years, depending on the company(s) and the industry.

5 Future Direction
Throughout its seven-year span the DAMA project took on many different efforts, achieved numerous goals and made significant impact on the industry. During this time, there were two major focuses: 1) systems analysis of the supply chain and 2) the development of tools for sharing data and making collaborative decisions across the supply chain. These two themes ran concurrently throughout the project.

With the conclusion of the DAMA Project research by the industry and national laboratory teams, the intellectual property developed during the Project, has been turned over to the Textile Clothing Technology Corporation [TC]² and the DAMA Partners for use in the softgoods industry. Included in the intellectual property are available tools as listed in Section 8.

It is the opinion of the DAMA Project that VICS, ATMI, and AAFA would all be excellent places to nurture the model as a possible standard or guidelines for future collaborative supply chain initiatives. DAMA participated in the work of three Voluntary Inter-industry Commerce Standards (VICS) group committees: 1) Internet Commerce Committee, 2) Collaborative Planning Forecasting and Replenishment (CPFR®), and 3) Collaborative Transportation Management (CTM). The VICS Internet Commerce Committee is chartered with evaluating and recommending Internet standards to the VICS membership. The VICS CPFR® group promotes collaborative forecasting between retailers and suppliers. DAMA helped the VICS CPFR® committee with concepts of joint business planning and participated on the CPFR® advisory committee. The primary focus was on business processes and data sharing.

It is the expectation of the N-Tier CPFR® Committee that the DAMA N-Tier Collaboration Model work will be an entry point for mapping the general model to specific industry N-Tier models. [TC]² will continue to collaborate with VICS and incorporate some of the DAMA technologies, methodologies, and concepts into industry standards.

July 2003