Lean Manufacturing Above the Shop Floor

Case Studies from Missile and Aircraft Supply Chain Projects

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Abstract

Lean manufacturing is playing a significant role in industry, as well as in DoD strategies for transformation. While lean concepts typically are applied to production processes, the potential savings in today's information-intensive operations is even greater above the shop floor. This paper presents the results from two projects applying lean concepts to information flows in supply chain management. The first project involves the missile industry and focuses on the preparation, validation, and delivery of technical data from Raytheon Missile Systems (RMS) to its suppliers. A cost savings of over $15M annually is projected for the missile prime through the elimination of non-value added activities and automation of portions of the process. A significant reduction in cycle time for the process was also documented. As a result, three missile programs have adopted the automated processes, and the prime intends to adopt the change company wide. The second project concentrates on supplier development activities with the Air Force F-22 program. Using Value Stream Mapping, the project identified process improvements and automation opportunities on the supplier side of the technical data delivery process. The project included both the Request for Quote process and the Build to Print Order process. The savings projected for a single sheet metal supplier to Lockheed Martin fighter programs is over $230K annually. The potential cost savings across the F-22 program supply base is over $1M per year. These two projects show how Lean concepts can lead to dramatic improvements when applied to supply chain information processes. Both projects used an international standard for electronic exchange of the technical data package. This allows a supplier to use the automated solution with multiple customers in either defense or commercial industry. Both projects highlight the need for involvement across functional areas within a company and from the supplier base.

Introduction

The concepts of Lean Manufacturing are well known and are being applied widely in industry. As industry moves forward in deploying lean concepts, it is important to recognize the potential benefit for attacking waste in above-the-shop-floor processes. While the benefits are significant in production, this typically constitutes less than 30 percent of the total cost of a product. Furthermore, the distributed, collaborative nature of manufacturing today depends extensively on efficient and cost-effective information processes among sites and throughout supply chains. Prime manufacturers go outside of their own organizations for over 2/3 of the parts and assemblies that they need. Thus, the communication processes have a very significant impact on overall performance. This paper examines two related projects that focus on information processes with the supply chain and how lean concepts can provide substantial benefits. The projects address different aspects of the process for delivery of the technical data package to suppliers.

The paper begins with some background information and then presents the two projects and their results in detail.

Background

During the past decade industrial primes have come to depend more and more on the performance of their supply chains. The use of the Internet and supply chain management software applications continue to grow. The delivery of technical data packages (TDPs) to suppliers over the web is an obvious target for lean concepts. As depicted in Figure 1, the TDP is often a significant amount of paper documents to be collected, reviewed and validated, delivered, and processed by the supplier. Applying lean concepts and automating the process can decrease cycle-time and costs while improving the quality of the results.

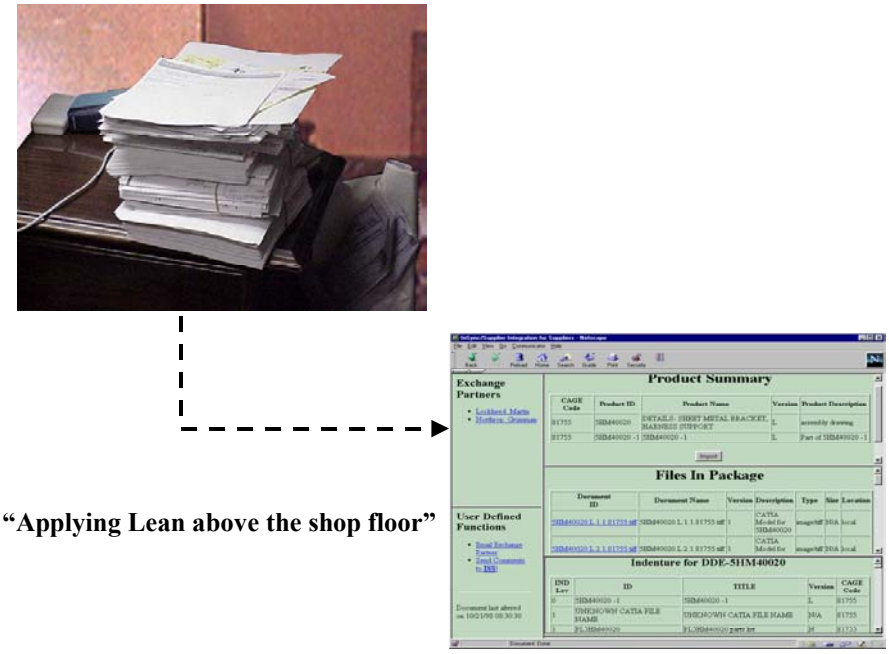

Figure 1. Automating Technical Data Packaging Processes

With support from Navy and Air Force Manufacturing Technology programs, two initiatives are proving the technological feasibility and benefit of automating the TDP delivery process. These programs involve different weapon systems and different primes, and one focuses on the prime's TDP activities while the other focuses on those of the suppliers. What they have in common is the concept of automating the information exchange processes using a neutral data format. This allows the prime to effectively use a commercial Product Data Management (PDM) system without dictating the PDM system or applications used by suppliers. Furthermore, the neutral data format used in both programs is based on the International Standard ISO 10303, so that suppliers and primes can be confident that others will be capable of reading the neutral format. Figure 2. depicts the type of data included in the neutral format specification. Both project

teams recognized the need to eliminate waste in the process prior to automation. The following paragraphs introduce the two initiatives.

The first project is the Supply chain Technologies for Affordable Manufactured Products (STAMP). Sponsored by the Navy ManTech program STAMP targets affordability improvements in the missile industry, working with Raytheon Missile Company. The STAMP program automated the process for collecting, reviewing, validating, and delivery of the TDP. Consequently, the benefits of the application of lean and automation of the process occur primarily inside of Raytheon.

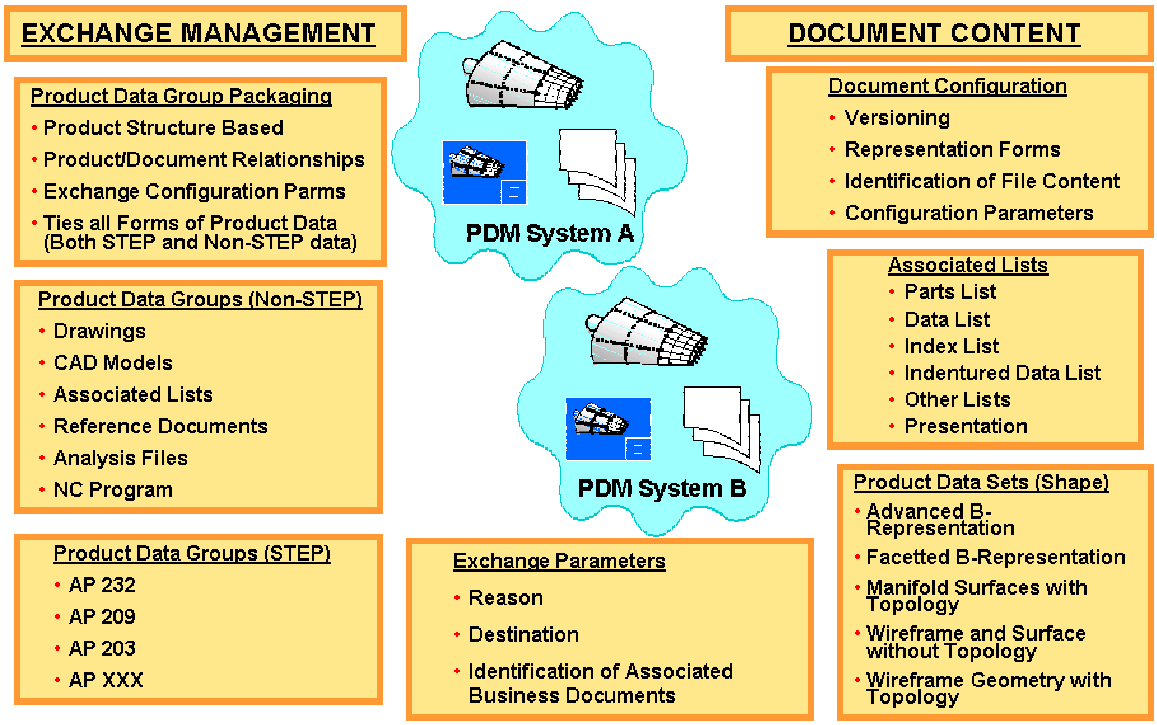

Figure 2. Information Content of the Technical Data Package Format

The second project is the Validating Advanced Supply chain Technologies (VAST) program. Sponsored by the Air Force ManTech program, VAST targets the F-22 supply chain for Lockheed Martin Aerospace. In contrast to STAMP, the VAST program applied lean concepts to the suppliers' activities for receipt and distribution of the TDP.

It should be noted that several of the STAMP and VAST suppliers supported both Lockheed Martin Aerospace and Raytheon Missile Company. In general, these suppliers maintain a consistent process internal for the TDP, regardless of the originating company.

Supply-chain Technologies for Affordable Manufactured Systems (STAMP)

Building on a previous DARPA project, the STAMP Project began in July 2001 to improve affordability of Navy missile systems. STAMP piloted technology that

enabled Raytheon to deliver digital technical data packages ("TDPs" See Figure 3) to its suppliers.

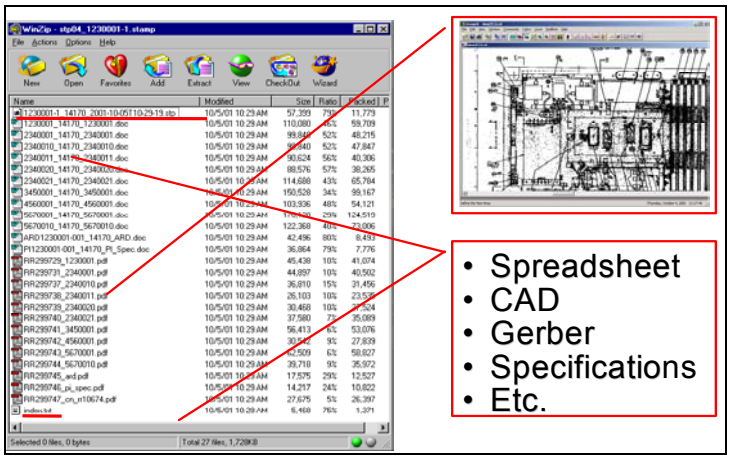

Figure 3. Example Technical Data PackageContents

The project team includes the Advanced Technology Institute, Raytheon Missile Systems (RMS), ICF, ISS, ITI and 16 Raytheon suppliers from the AIM-9X (Sidewinder) and Tactical Tomahawk Navy weapons systems. The project verified that it was possible to exchange complete and accurate PDM information between different PDM systems using international standards for data exchange. More importantly, it demonstrated that preparing and delivering TDPs in digital form dramatically reduces labor and cycle times over paper-based delivery.

STAMP Deployment Scenario at Raytheon

The primary objective of the STAMP for SPANS project was to deploy STAMP in production to impact missile affordability. In order to encourage widespread deployment, the team needed to validate the business case for using STAMP to assemble and deliver digital TDPs to the missile supply chain. The project deliverables included:

- Deployment of STAMP technology in the Raytheon supply chain for two Navy missile systems (Figure 4).

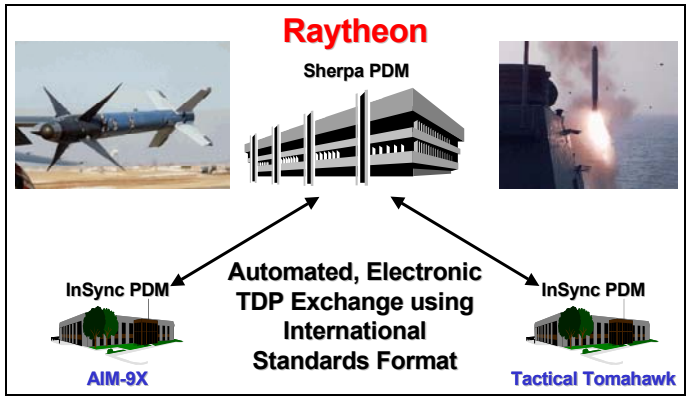

Figure 4. STAMP for SPANS DeploymentScenario

- Comparison of cost and cycle time requirements for manual and electronic TDP preparation and delivery. TDPs were prepared using STAMP software and using the current manual method (parallel deployment), providing a one-to-one comparison of TDPs for both methods. The sample size was approximately 100 TDPs. Labor and cycle times were either recorded directly, or estimated based on internal Raytheon and supplier metrics.

- Development of a detailed business case addressing the cost and benefits of electronic TDP preparation and delivery. Estimates for commercial deployment were established, including development costs, installation, training, licenses, computer software and system requirements, and maintenance.

STAMP Software Architecture

STAMP technology provides the capability to assemble an entire TDP in electronic form at the push of a button.

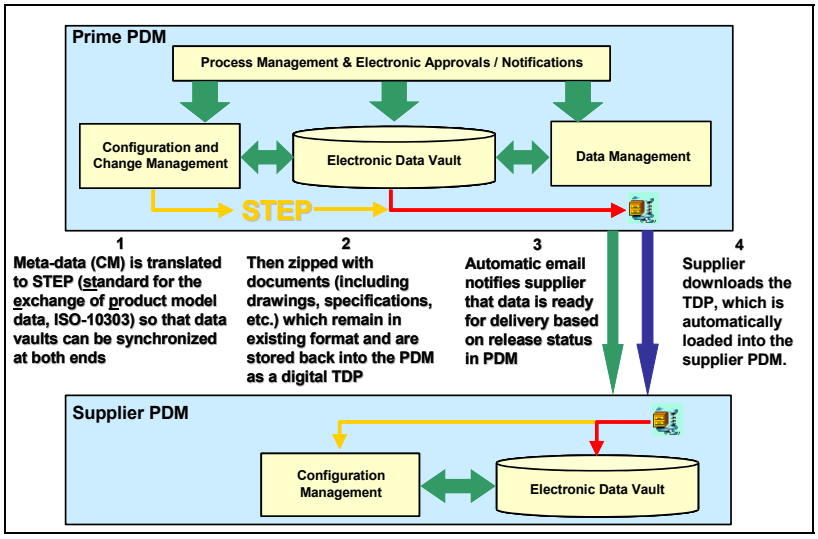

Figure 5. STAMP Data Exchange Architecture

Data to be included in the TDP is selected based on STAMP business rules and workflow incorporated into the Raytheon's Sherpa PDM system.

The STAMP translator converts the product structure and PDM configuration management information into the ISO 10303 international standard format for PDM data exchange (STEP PDM Schema), then compresses this data, along with technical data files, into a single package and stores this package back into the prime PDM system (Figure 5).

Suppliers are automatically notified by e-mail that a TDP is available. Suppliers then access the TDP at their convenience in the Prime's PDM system using the Internet, and then securely download it to a computer at the supplier site. Once the package is downloaded, STAMP software automatically decompresses, translates and loads the TDP data into InSync, a low cost PDM system that is installed on the supplier computer (see Figure 6 for comparison of manual versus STAMP processing of TDPs at Raytheon).

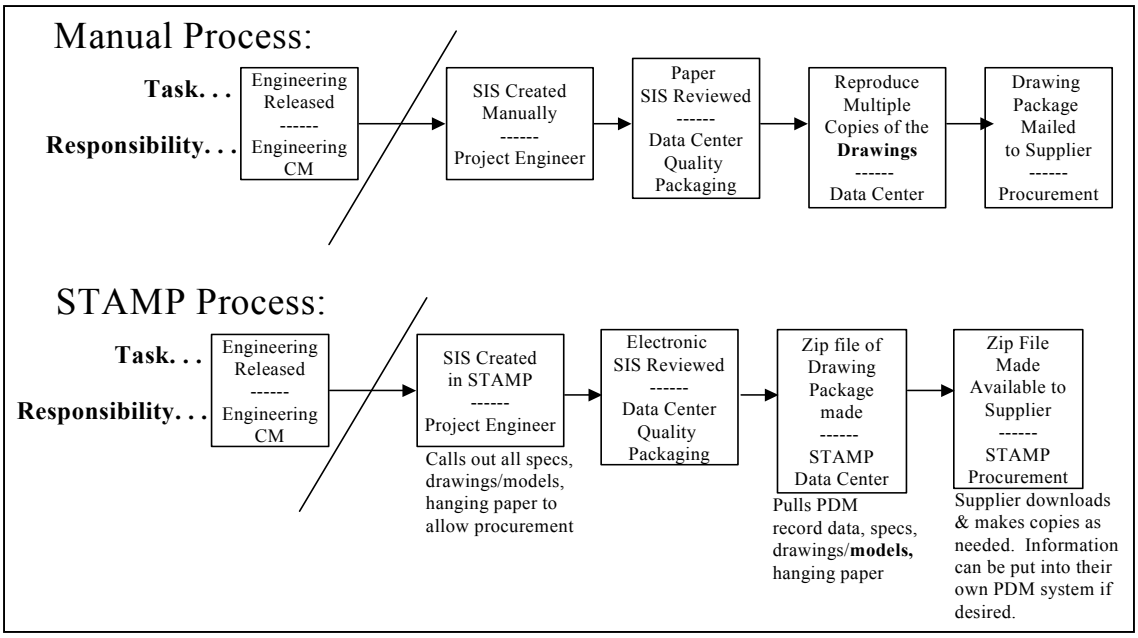

Figure 6. Manual Versus STAMP TDP Process

STAMP software enables suppliers to leverage the product structure and configuration management data from Raytheon's PDM system, along with the technical data files (drawings, CAD files, etc.) they would normally receive in a paper TDP. They then access and manage this data in their own InSync PDM system, distributing the data for review in electronic form. Because the data is automatically loaded into the PDM at the supplier, immediate use in downstream applications is enabled. Also, because STAMP uses an international data standard for delivery of TDPs, suppliers can receive and automatically load TDPs from other PDM systems that support the standard.

STAMP Project Results

The project demonstrated that deploying STAMP technology at Raytheon reduced labor by 50%-88% (depending on the TDP).

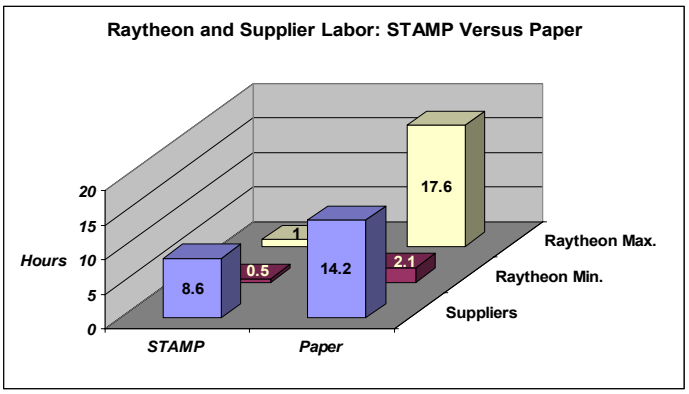

Figure 7: STAMP Reduced Labor at Raytheon by 50% - 88% and at Suppliers by 39%

This labor reduction corresponds to cost savings across all missile programs ranging from $9M to $15.8M per year. Supplier savings averaged 39%, corresponding to an estimated $1.8M savings per year if STAMP was deployed across all Raytheon missile programs (Figure 7).

The project also demonstrated dramatic cycle time reductions at both Raytheon and its suppliers. Technical data packages processed using STAMP technology required 59% lower cycle times than traditional paper methods at Raytheon. Likewise, suppliers using STAMP technology to receive and process TDPs demonstrated cycle time reductions averaging 95% over paper TDP delivery (Figure 8).

At the beginning of the STAMP project, Raytheon had several 6-Sigma teams working to reduce the cost and cycle time associated with data delivery. Based on the success of the STAMP Project, Raytheon has reassigned two of these teams to other efforts.

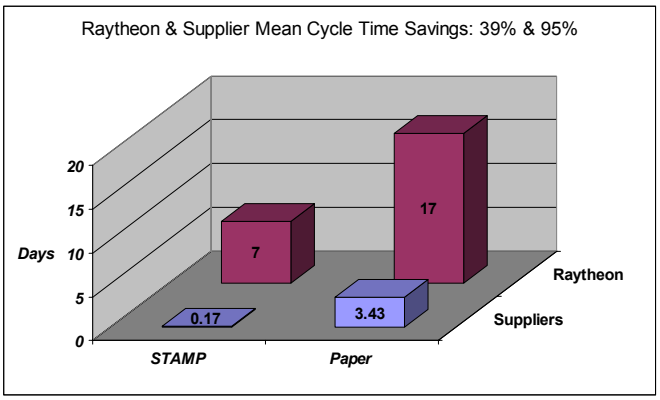

Figure 8: Raytheon & Supplier Mean Cycle Time Savings: 39% & 95%

Raytheon is also planning to reassign approximately 50% (and possibly up to 70%) of its 10-member Data Center staff, due to the labor savings realized through using STAMP technology for data exchange. Raytheon has already deployed STAMP technology in production on their Tactical Tomahawk, Sidewinder, and EKV programs. All new TDPs delivered to suppliers that participated in the STAMP program are also processed using STAMP. In an effort to spread the technology to other programs, Raytheon has initiated an aggressive training program for all personnel involved in the creation and delivery of technical data packages, conducting at least two training sessions per month.

With its digital, standards-based TDP infrastructure in place, Raytheon is now working with the STAMP team on the next phase of STAMP. STAMP Phase II will run from May 2002 to June 2003 and will evaluate the business case for bi-directional exchange of digital data between PDM systems. Bi-directional data exchange will facilitate design collaboration, response to quotes, and change management in the Raytheon supply chain. STAMP Phase II will also investigate the benefits of automated translation of CAD data into international neutral standard format prior to delivery to suppliers that use different CAD systems than Raytheon. The results from both Phases of STAMP are expected to be widely applicable in DoD.

STAMP technology proved to be an effective tool for significantly reducing both cycle time and labor costs for TDP delivery and improving product quality in the Raytheon missile supply chain. The STAMP team estimates the cost of a commercial deployment of STAMP ranges from $300k - $500k at a large prime and $25k or less at each supplier, so there is a significant return on investment within the first year of deployment. While the benefit derived from cost savings is obvious, cycle time reduction provides less tangible but perhaps even more important benefits. For example, cycle-time reductions can help meet an urgent need for replacement weapons, as was observed during both the Gulf War and the war in Afghanistan.

STAMP also demonstrated that the STEP ISO 10303 is an effective format for exchanging PDM information between heterogeneous PDM systems. Suppliers were able to virtually duplicate all Raytheon configuration management information in their own PDM system at the push of a button.

The primary objective of the STAMP for SPANS project was to deploy STAMP in production to improve missile affordability. In order to achieve this, the team needed to validate the business case for using STAMP technology in the missile supply chain. The goal of SPANS, which sponsored the STAMP effort, is to move developing technologies into Navy weapons systems to improve affordability. In this case, both objectives were achieved.

Validating Advanced Supply-chain Technology (VAST*)*

The VAST program was one of five Air force ManTech initiatives to help drive affordability concepts throughout the defense industrial supplier base by validating and stimulating improvement in small and medium sized enterprises (SME) as a result of supplier development initiatives. The validation of affordability concepts focused on the development of the business case for suppliers. The VAST Program focused on two technology activities for SME supplier improvement: 1) on the utilization of the principles embodied in Lean Deployment at the SME, and 2) digital communication of the Technical Data Package (TDP) data to the SME. Working with the F-22 System Program Office, the program addressed key issues facing the Air Force in an era of increased outsourcing and reliance on supplier capabilities, and increasing emphasis on affordability.

DoD Program cost cutting initiatives are creating a continuing pressure for contractors to provide goods and services better, faster and cheaper. The VAST Program extended the concepts of "lean" manufacturing and information exchange to enable SMEs to improve affordability.

A part of the VAST Program was to apply lean concepts to the exchange, review, and processing of electronic technical data packages (TDPs) in the supply chain. As shown in the Figure 9 below, this represents a proactive effort to optimize the information flow value stream, providing the standards-based infrastructure necessary to achieve the tangible benefits resulting from improvement in the technical problem solving and product flow value streams.

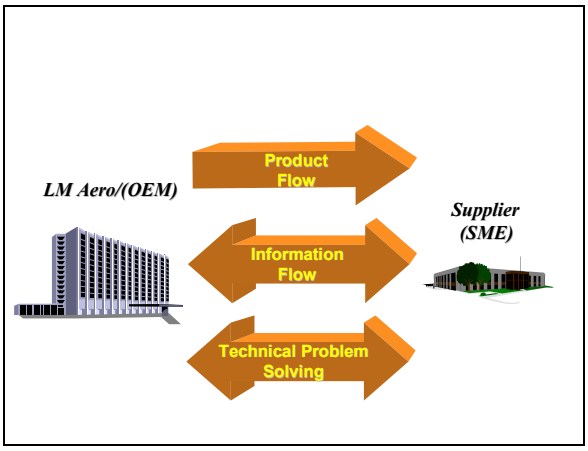

Figure 9 VAST Addresses Information Flows

From inception, this supplier development activity sought to develop a broadly usable solution that met the needs of both prime contractors and suppliers. VAST also uses the ISO 10303 family of standards to facilitate the data exchange process. By adopting a standardized approach, it provides suppliers the ability to efficiently meet the needs of all their customers according to their best business practices. Using VAST tools, suppliers can exchange and manage the technical data they receive from all of their customers in a single system. It is intended for broad scale deployment and is simple, scalable, and affordable. Personnel requirements, technology infrastructure, and overall cost are within the reach of even the smallest suppliers.

The VAST program was lead by the Advanced Technology Institute (ATI). The program team consisted of ATI (providing program management, technical, and business case expertise) Lockheed Martin Aeronautics Company (the DoD prime contractor), and STEP software providers Integrated Support Systems, Inc. (ISS), and Theorem Solutions and a selected SME supplier to the F-22 program. The supplier selected to participate in the VAST program fit the profile of active F22 subcontractors that were receiving TDP's from LM Aero on a consistent basis. In addition, this supplier of sheet metal parts was considered as a "typical representative" of one of sixty-three F-22 sheet metal suppliers. As such, data related to this supplier could be extrapolated across the entire family of sheet metal parts provided by suppliers to the F-22.

Representatives from the SME organization were provided training on the software tools that were included as part of the software toolkit on the VAST program. Following the tool training efforts, an overview of the overall process was provided as a lead-in to the efforts for documenting the current and future flow for the targeted activities.

One of the key objectives of the VAST program was to address current processes, involving TDP handling at LM Aero and their SME's, and potential improvements to those processes. The VAST team focused on two of the SME's paper-based processes involving TDP handling. The first was the Request for Quote (RFQ) process and the

second focused on their Post-Purchase Order (PO) activity that deals with contract review and planning.

Once the tools were in place at the SME's facility, manual and automated TDP's were prepared by LM Aero and provided for processing. The SME processed the TDP's in both the current and future process flows, documenting the process times with both flows for later evaluation on the business case.

The VAST team adopted an approach from LM Aero's Lean Manufacturing team philosophy by using a Value Stream Mapping (VSM) event to capture the activities, span times, labor, wait states, movement stages, waste areas, etc., within the RFQ and PO processes. This comprehensive mapping event produced a flow chart of each process, detailing activities in the current ("as-is") process with paper TDP's, as well as the future ("to-be") process utilizing an automated approach.

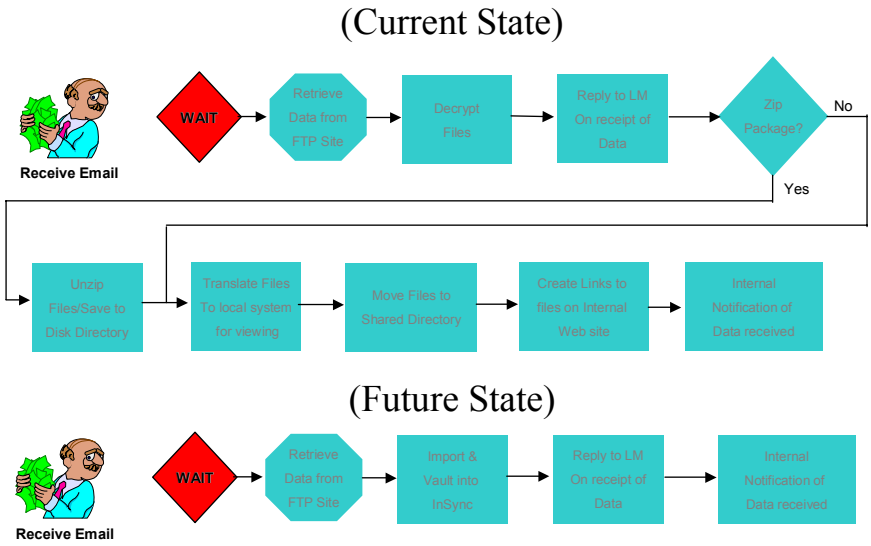

Figure 10. Value Stream Mapping Event Example

VAST Project Results

The Lean supplier development initiative focuses primarily on streamlining core manufacturing functions within a supplier's organization. VAST has also undertaken supplier development through data exchange capability enhancement and automation. ATI, LM Aero, ISS, and Theorem Solution demonstrated how suppliers can electronically receive, review, and process standard technical data packages (TDP) for responding to request for quotes (RFQs) and for Purchase Orders (POs).

The business case represents an accumulation of input from a current supplier to the F-22 program and includes man hour estimates for specific technical data processing tasks, average man hour costs, and projections for future technical data exchange savings. The projected savings for the supplier was many times more than the cost of deployment.

Cycle time reductions may have a more significant impact. Remembering that the end customer for the F-22 aircraft is the warfighter, a reduction in cycle time could mean that four aircraft, rather than three, are available for deployment when they are needed in the theater.

The project results were calculated for both the RFQ and PO processes. Each set of activities shows cycle time reductions and cost avoidance for the single selected supplier and the F-22 parts currently processed. The selected supplier also provides similar parts for Lockheed Martin on five other fighter aircraft. Results have also been extrapolated to address these programs. In addition, sixty-three total suppliers have been identified as providing F-22 parts in the same part families as those delivered by the selected supplier. As such, business case results have also been projected across this known supplier base.

Table 1. VAST Selected SME (single supplier) – Annual RFQ Labor Costs

Annual RFQ Processing	Total Part #'s Processed	"As is" Direct Labor Hours	VAST Enabled Direct Labor Hours	"As is" Direct Labor Cost (@ $65/hr)	VAST Enabled Direct Labor Cost	Annual Cost Avoidance (@ $65/hr)
F-22 RFQ's	246	56 Hours	36 Hours	$3,640	$2,340	$1,300
F-22 PO's	82	2,009	1,640	$130,585	$106,600	$23,985
Combined RFQ/PO Cost Avoidance F-22 Program						**$25,285**
All LM Fighter RFQ's	2289	522 Hours	348 Hours	$33,930	$22,620	$11,310
All LM Fighter PO's	755	18,498	15,100	$1,202,370	$981,500	$220,870
Total Cost Avoidance All Lockheed Martin Fighter Programs						**$232,180**

Table 2. Sixty-three F-22 Sheet Metal Suppliers – Annual RFQ Labor Costs

Annual RFQ Processing	Total Part #'s Processed	"As is" Direct Labor Hours	VAST Enabled Direct Labor Hours	"As is" Direct Labor Cost (@ $65/hr)	VAST Enabled Direct Labor Cost	Annual Cost Avoidance (@ $65/hr)
F-22 RFQ's	10,332	2,268 Hours	1,512 Hours	$147,420	$98,280	$49,140
F-22 PO's	3,402	83,349	68,040	$5,417,685	$4,422,600	$995,085
Combined RFQ/PO Cost Avoidance F-22 Program						**$1,044,225**

Table 3. VAST Selected SME (single supplier) – Annual RFQ Cycle Time

Annual RFQ Processing	Total RFQ's	"As is" Cycle Time	VAST Enabled Cycle Time	Projected Cycle Time Reduction
F-22 RFQ's	6	1,350 Hours	756 Hours	44%
All LM Fighter RFQ's	56	12,600 Hours	7,056 Hours	44%

Table 4. VAST Selected SME (single supplier) – Annual PO Cycle Time

Annual PO Processing	Total Part #'s	"As is" Cycle Time (per PO Package)	VAST Enabled Cycle Time	Projected Cycle Time Reduction
# F-22 PO's	246	221 hours	126 Hours	43%
# All LM Fighter PO's	2289	221 Hours	126 Hours	43%

VAST Summary

The business case results realized from the VAST program show a clear, measurable set of outputs for a single supplier relative to a single weapons systems program; for a single supplier relative to their DoD related work for a single prime contractor; and for a representative set or "class" of similar suppliers on a single weapon system program. While it does not appear to be cost effective to implement digital data exchange capabilities for a single program (annual projected savings of $25k), it becomes extremely cost effective when applied against all of the similar work that the selected supplier performs for the prime.

In this case, the selected SME provides similar sheet metal parts for five Lockheed Martin fighter programs. Since the digital TDP data is generated by the same systems within Lockheed Martin, and the same software tools and processes can be utilized to receive and access the data within the SME organization, the annual projected savings of $232,000 for the SME become significant. Assuming a $65 per hour labor rate for the SME, this amounts to almost 2 full time equivalent salaries in the SME shop. Further projections across the set of sixty-three SME sheet metal suppliers for the F-22 program equate to program savings of over $1,000,000 annually.

The projected cost avoidance scenarios, coupled with total cycle time reductions of 44% and 43% for the Request for Quote and Purchase Order processing, present a strong case for encouraging the rapid deployment of digital Technical Data Packages across all sectors of the Defense Industrial Base.