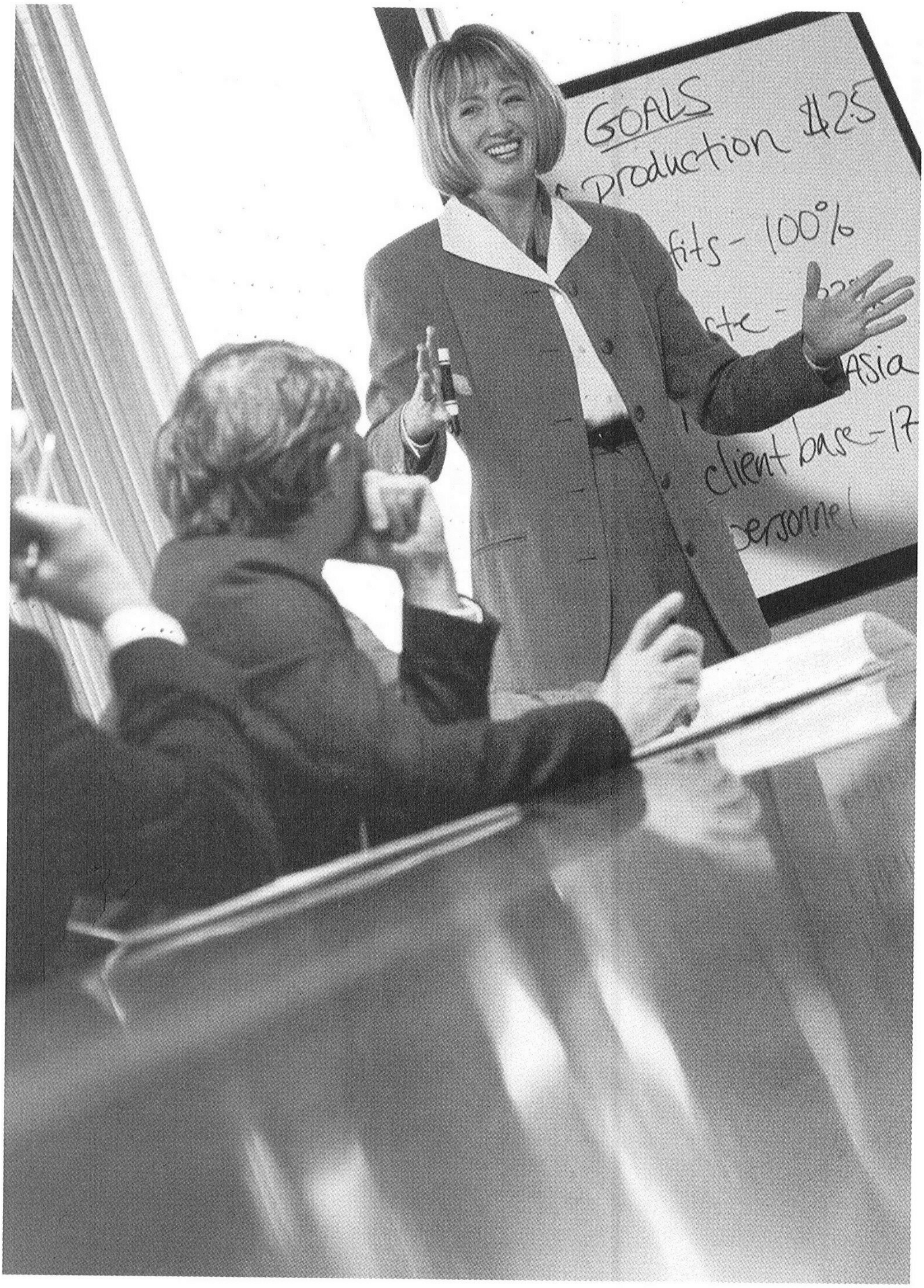
GOALS
production $125
fits - 100%
Asia
client base - 17
personnel

TAMING THE AEROSPACE SUPPLY CHAIN—A CASE STUDY IN ORGANIZATIONAL INTEGRATION

DEWAYNE SEARCY, PH.D., BRADLEY GREENE, PH.D. AND JAMES REEVE, PH.D.

Integrating suppliers and customers to capture supply chain efficiencies and effectiveness is critical in today's increasingly competitive environment. However, knowing this and doing it are two different matters. The methodology described here is an effective means to develop inter-organizational coordination. To achieve this coordination companies must first be made aware of the fundamental dynamics of supply chains. Awareness can disengage the individual personalities within different organizations and allow members of the supply chain to objectively view their value stream. Then, the individual organizations can define and measure the current state of their supply chain and finally agree to corrective actions that benefit the entire supply chain. Thus, our question is, how do firms that are traditionally isolated in their supply chain dealings introduce a greater degree of cooperation to their relationships? We will provide an answer to this question with a supply chain case study.

Integrating suppliers and customers to capture supply chain efficiencies and effectiveness is critical in today's increasingly competitive environment (Spekman, Kamauff, & Myhr, 1998). However, knowing this and doing it are two different matters. Organizations must overcome the tendency to manage their supply chain relationships strictly on the basis of power and *zero-sum* behaviors, because significant benefits can accrue to all supply chain participants through cooperation. Thus, our question is, how do firms that are traditionally isolated in their supply chain dealings introduce a greater degree of cooperation to their relationships?

Mentzer et al. (2001) define supply chain management as, "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across business within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" (p.18). This definition has two basic features: coordination both *within* organization and *across* organizational boundaries. Intuition and experience suggest cooperation within the organization will often precede cooperation across organizational boundaries. For example, a firm must develop an internal forecasting process before using such forecasts as a supply chain planning mechanism. In addition, facilitating change is often easier within four walls of one's own organization than across organizational boundaries.

"Our experience shows that overcoming competitive behaviors requires a forum, or process, for initiating a more cooperative posture."

Intra-organizational change benefits from established protocols and controls that can be used to communicate and monitor change. These protocols do not often exist between organizations, thus challenging supply chain cooperation. A mechanism is needed to level organizational capabilities in order to foster cooperation. Our experience shows that overcoming competitive behaviors requires a forum, or process, for initiating a more cooperative posture. This paper describes such a process for initiating supply chain cooperation for firms that have had a limited history of supply chain cooperation.

METHODOLOGY

This case study was conducted with three firms from an aerospace supply chain, consisting of a prime contractor, a major subcontractor, or first tier supplier (FTS), and a minor subcontractor or second tier supplier (STS). The cornerstone of the methodology is the Supply Chain Integration Workshop (SCIW), discussed later. The SCIW was the first time representatives from all three firms gathered in one place. The workshop's objective was to facilitate cooperation across the supply chain segment by identifying and resolving inefficiencies within and across the firms. In addition to the workshop, data were collected via surveys and interviews with key personnel.

The supply chain segment under study manufactures and delivers a major component (MC) on a weapon sold to the Department of Defense (DoD). As of March 2001, the MC for the supply chain was a newly designed component in the Engineering Manufacturing Development (EMD) phase.

SUPPLY CHAIN INTEGRATION WORKSHOP

The objective of the SCIW is to bring representatives from each supply-chain tier together to begin a dialogue across the supply chain with the goal of increasing cooperation, communication, and coordination within and between companies. The SCIW is designed to motivate supply chain cooperation by demonstrating the potential for either cost savings and/or customer value enhancements. This is accomplished through a five-step process, as follows:

1. Develop an understanding of supply chain problems.

2. Baseline intra- and inter-organizational integration.

3. Identify action items for improving the supply chain.

4. Assign responsibility for executing action items.

5. Follow-up.

DEVELOP AN UNDERSTANDING OF SUPPLY CHAIN PROBLEMS

The SCIW begins with a value-stream simulation (i.e., an adaptation of the Massachusetts Institute of Technology Beer Game). The idea is to actively engage the participants on how a lack of communication and coordination across a supply chain negatively affects all members of the supply chain (i.e., the development of the whiplash effect). As is often the case, a simulation is an excellent way to begin seeing the issues that are usually too large and complex to understand within a daily context. We use simulations to motivate the workshop and form insight. For example, at the conclusion of the simulation a senior manager of the STS commented that the whiplash effect was exactly what was happening to them.

BASELINE EXTENT OF INTERNAL INTEGRATION WITHIN EACH COMPANY INVOLVED

Before companies can effectively manage their supply chain each one must have a good grasp of their individual capabilities. This is necessary so that capabilities can be matched across the supply chain. Thus, step two involves base-lining the internal and external integration within and between each participating company. This base-lining effort requires on-site data collection prior to the workshop. Without these data, it is impossible for the workshop to move beyond mere opinions and guesswork.

Our experience shows an individual firm's performance history does little for comparing performance across firms with different performance histories. That is, a firm's opinion about their performance based upon their historical baseline is irrelevant to their relative performance in the supply chain. Baseline data provide supply chain participants an ability to discuss respective capabilities through a common reference point. The capability assessment is used to discover the *gaps* in supply chain cooperation, which can be used to motivate their change or removal.

The research team administered the Lean Enterprise Site Assessment (LESA) to accomplish a thorough, objective, and accurate (valid) pre-workshop on-site assessment of each firm. The LESA was initially developed as a framework for assessing over 60 Lean implementations worldwide in 1999. Further improvements were made to the instrument and additional pilot tests were conducted to increase its validity.

"Our experience shows an individual firm's performance history does little for comparing performance across firms with different performance histories."

The LESA is an instrument that measures the extent of various Lean tools and techniques employed at a company, while also collecting key supply chain performance metrics in an effort to correlate supply chain performance with Lean infusion.[1] Tables 1 and 2 list the elements measured by the LESA. As the Tables indicate, there are several dimensions in measuring the extent of internal and external integration. For the instrument to be beneficial to the participating companies there must be a mechanism for interpreting and comparing organizational performance. An algorithm was created using the Analytical Hierarchy Process, developed by Thomas Saaty, to transform the raw data collected at each site into a summary score we call the Lean Infusion Score (LIS) (Saaty, 1980).

The LIS range from 0 to 100, with 100 representing complete Lean infusion. The overall summary score for each firm is comprised of three Lean infusion sub-scores for each of the Lean supply chain dimensions: (1) Supplier Integration Score, (2) Lean Production Score, and (3) Distribution Integration Score. The higher the score the better the company is at using Lean tools and techniques to improve its intra-firm and inter-firm integration. Figure 1 displays the LISs for each company.

Overall, none of the companies are operating on a world-class level; however, the Prime and STS appear *on the journey* and have similar infusion scores. With an overall score of 23, it appears the FTS is not as advanced with its Lean implementation as the other two companies. This is a critical insight, because the supply chain segment depends on the FTS's ability to integrate both upstream and downstream. In essence,

TABLE 1. LEAN PRODUCTION ELEMENTS MEASURED BY LESA

Lean Production Element	Definition
5S	Organization and daily maintenance of the work area.
Total Productive Maintenance	Operators are incorporated in the daily maintenance activity.
Set-Up Reduction	A concentrated effort to decrease the amount of time needed to prepare material and equipment for changing over from product to product.
Standard Work	The establishment of an optimal flow of work activities within a cell or on an assembly line.
Method Sheets	Guidelines or instructions that graphically depict standard operating procedures.
Quality Assurance	A collection of tools used to detect and eliminate defects.
Mistake-Proofing	The use of fixtures and tools to eliminate or reduce the possibility of errors.
Production to TAKT Time	Pace of demand that is used to determine the required pace of production.
Flow Cells	The grouping of product families into close proximity to eliminate unnecessary material movement.
Visual Controls	The use of visual signals to communicate information about the status of the production line.
One-Piece Flow	The ability to produce one part at a station at a time.
Mixed-Model Production	The ability to make several products on the same line in a random or sequence order.
Point-of-Use Storage	The preparation of work areas for the direct presentation of supplied materials.
Design for Manufacturing	The incorporation of manufacturing capabilities in the design phase of a product in order to make necessary engineering changes due to process capabilities before the new product reaches the production stage.
Complexity Reduction	The decreasing of parts or operations needed for a product by increasing component usage and simplifying the design.
Kanban/Pull Production	The communication system of the manufacturing environment. As materials are consumed at a downstream station, signals are sent back to previous steps in the production process to pull forward sufficient materials to replenish only those materials that have been consumed.
Kaizen Events	A focused improvement exercise during which a cross-functional team spends 1 – 3 days improving a production cell, line, or process.
Ergonomic Design	The design of processes to natural human movements, postures, and environment.
Cross-Training	The training of the workforce to perform multiple tasks.

TABLE 2. INTEGRATION ELEMENTS MEASURED BY LESA

Supplier and Distribution Integration Element	Definition
Production Development Integration	The integration of supplier design capabilities and sharing of information so as to enhance, improve, and shorten the overall product design process.
Blanket Orders	A long-term purchasing agreement that eliminates repetitive purchase orders and therefore shortens the order-entry process and significantly reduces paperwork.
Kanban Replenishment	An inventory strategy in which the supplier builds their schedule solely to replenish the consumed inventory of a downstream factory, distribution center, or retailer.
Rate-Based Planning	The establishment of minimum and maximum bounds of capacity flexibility around future demands.
Supplier Broadcast	The sharing of MRP information with integrated suppliers.
Data Exchange	The electronic exchange of demand information between suppliers and manufacturers.
Point-of-Use Material Delivery	The delivery of materials by the supplier to the location (e.g., cell, assembly line, etc.) that the materials will be added.
Quality Certification	A supplier audit process, which over time eliminates the need for inspection of incoming materials.

* DC - distribution center
* MRP - Material Requirements Planning

LESA Scores Prime	
Overall	56
Supplier Integration	44
Lean Production	68
Distribution Integration	na

LESA Scores FTS	
Overall	23
Supplier Integration	6
Lean Production	39
Distribution Integration	23

LESA Scores STS	
Overall	54
Supplier Integration	56
Lean Production	49
Distribution Integration	56

0 – 40	41 – 74	75 – 100
Beginning the Journey	*On the Journey*	*Approaching World Class*

FIGURE 1. LEAN INFUSION SCORES

FTS's weak capabilities are acting as a constraint on the Prime's and STS's emerging supply chain capabilities. This is important knowledge in forming a supply chain improvement strategy.

While Figure 1 provides the companies with a high-level view of its supply chain, more detail data is needed to assist the companies' move toward successfully managing their supply chain. Table 3 decomposes the Lean infusion scores down to the Lean tool and technique level. Thus, each company is able to assess their capabilities in comparison with their partners. This detail is important in aligning rate broadcasts, demand planning, and execution signal information across supply chain partners. For example, the STS has a score of 90 for kanban replenishment under Distribution Integration, while the FTS scored a zero for kanban replenishment under Supplier Integration. This suggests the STS is well equipped to institute kanban replenishment with its suppliers; however, the FTS is not able, at this time, to accommodate the STS. This information provides clearly targeted supply chain improvement opportunities for the supply chain partners.

TABLE 3.
LEAN INFUSION SCORES FOR SUPPLIER AND DISTRIBUTION INTEGRATION

	Prime	FTS		STS	
Integration Element	SI	DI	SI	DI	SI
Production Development Integration	17	95	15	0	0
Blanket Orders	0	0	9	20	78
Kanban Replenishment	100	0	0	90	58
Rate-Based Planning	0	20	0	0	75
Supplier Broadcast	50	0	16	78	75
Demand Data Exchange	100	100	0	80	100
Point-of-Use Material Delivery	100	10	10	100	15
Quality Certification	85	0	2	100	80
SI = Supplier Integration DI = Distribution Integration					

CREATE MUTUALLY AGREEABLE ACTION ITEMS FOR IMPROVING THE SUPPLY CHAIN

To facilitate the discussion between companies, two maps were developed from the information gathered via site visits and the LESA. The first map is the Supply Chain Metrics Map (see Figure 2). One of the objectives of the Supply Chain Metrics Map is to create awareness about overall supply chain performance. As can be seen, the supply chain has a number of challenges. The value added ratio (value added time divided by total lead time) is only 10.0 percent. Out of 112 days of throughput time, only 90 hours were identified as value added.

The most severe issues appear to be associated with the FTS. The FTS has five value added hours in their portion of the process, but consumes 60 days of lead-time. Part of the FTS's problem is the lead-time for raw materials. This is evidenced by nearly 180 days of raw material inventory at the FTS. However, it would be a mistake to assume that the solution to the supply chain's performance problems is found where the problem is residing. In reality, this is rarely the case. Rather, the solutions to problems reside within systems that may have their causes far removed from the

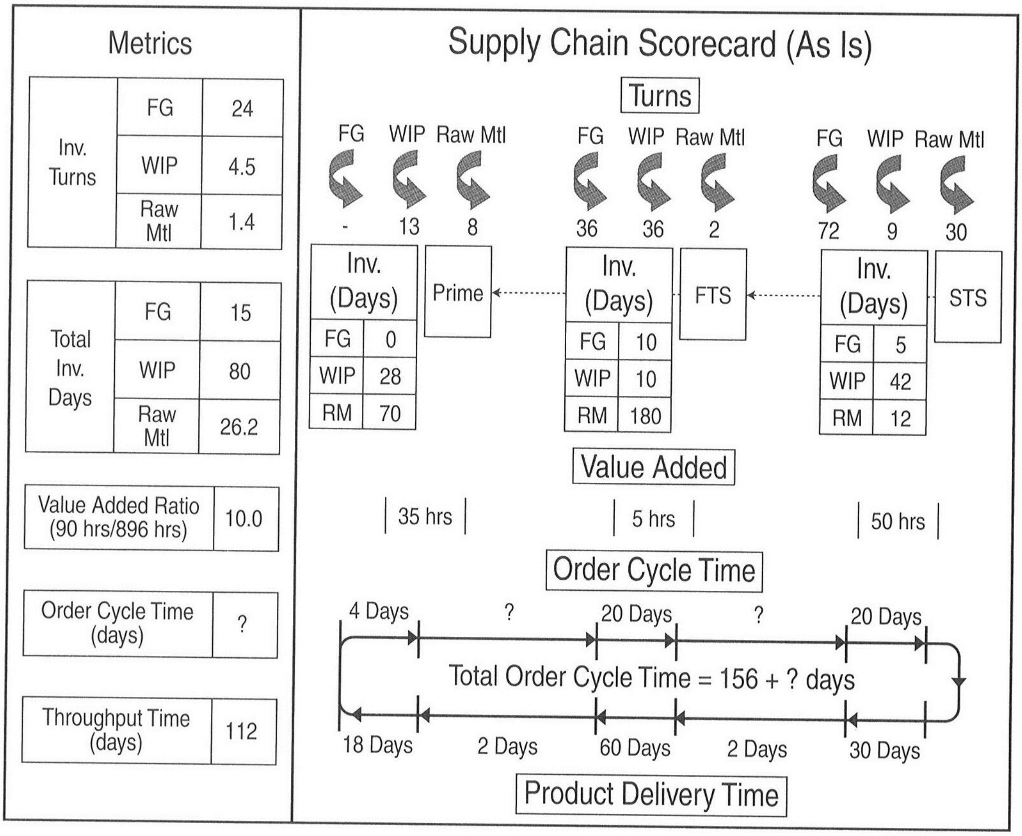

FIGURE 2. SUPPLY CHAIN METRICS MAP

place the problem is identified. Thus, we do not assume the metrics necessarily identify the location of the solution, only the location of the problem.

A second map, the Supply Chain Execution Map, helps identify the possible improvement sources. Figure 3 displays the Supply Chain Execution Map. This map visually details the flow of materials and information within each company and across the supply chain. This map is created prior to the workshop by the facilitators based upon the site visits, LESA results, and metrics (Figure 2). The map shows high-level information and execution flows across the supply chain, while highlighting areas for improvement and coordination. Specific supply chain details, such as demand planning frequency, pull vs. push, batch vs. flow, and upstream/downstream integration methods are displayed.

For example, the map in Figure 3 shows that the supply chain is driven by a classical Material Requirements Planning (MRP) system, with monthly planning *buckets*. Such an infrequent planning frequency causes weak visibility within the supply chain and "blind" execution. It would be like driving a car with your eyes closed and blinking them open every minute. Too much can change in a minute's time. In addition, the MRP system is run sequentially upstream. Such sequential MRP planning approaches

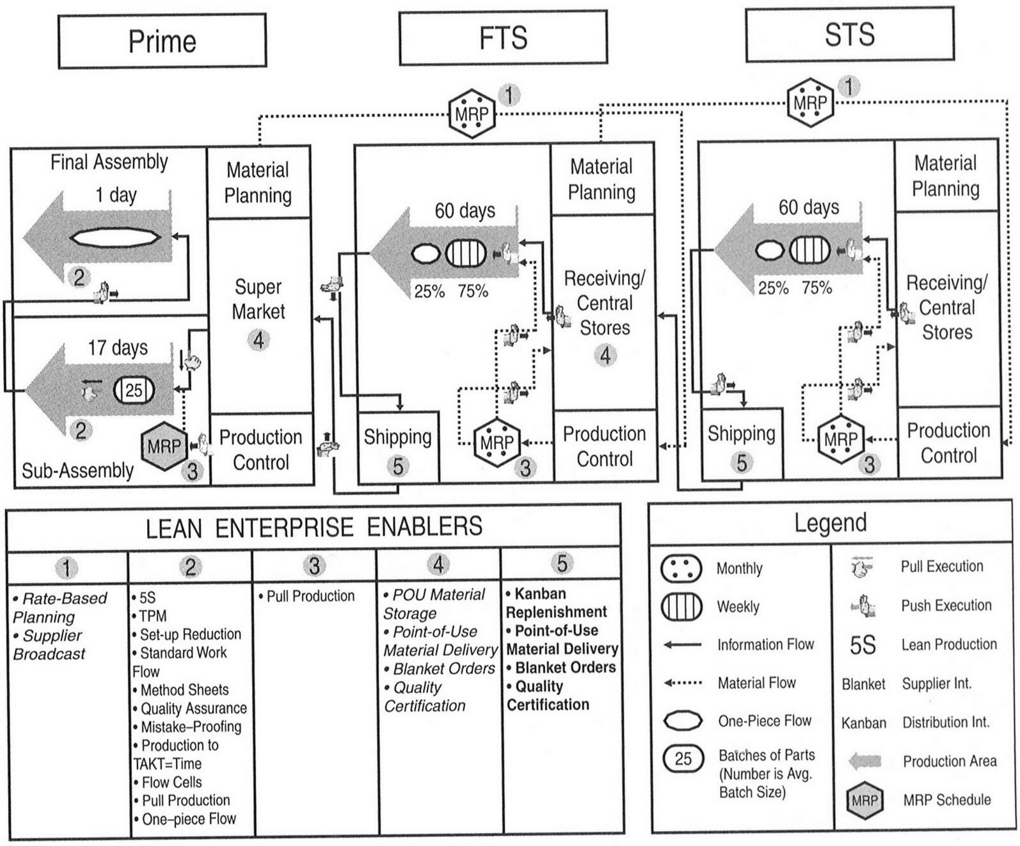

FIGURE 3. SUPPLY CHAIN EXECUTION MAP

combined with long lead-time responses give rise to the order inflation problem identified in the beer game simulation. That is, the Prime will input a demand plan into the MRP. The Material Requirements Planning will translate the demand into upstream purchase orders, adjusting for lead-time and safety stock requirements. The FTS inputs the purchase orders (distorted demand) into their MRP system, which in turn translates these into upstream purchase orders to the STS, adjusting for lead-time and safety stock. The purchase orders received by the STS systematically distort the actual demand known by the Prime. The map begins to hint at simultaneous demand broadcast by the Prime as the solution to remove this source of signal distortion.

With maps in-hand, breakout groups with members across the supply chain form to develop action items necessary to coordinate, communicate, and execute across the supply chain, in addition to continuing the Lean implementation efforts internally. There are two objectives for the breakout session. First, developing a list of action items for each site to complete to assist the site with implementing Lean (i.e., internal action items). Second, developing a list of action items the supply chain must complete to facilitate communication, coordination, and execution across the supply chain (i.e., supply chain action items). Table 4 displays the action items created by the participants in the SCIW.

While the actual action items listed are not groundbreaking and are indicative of the early stage of coordination, they are unique in that all three tiers worked together and agreed on those items with the stated goal of improving the supply chain. More than one of the participants in the SCIW commented that the workshop was, "A unique experience because they often do not get to work within the supply chain." Others mentioned that the unit-of-analysis (the supply chain of one program) makes it easier to talk with their customer.

TABLE 4. ACTION HEMS

Internal Action Items		
STS	FTS	Prime
Process flow chart	Streamline PO process	Check delivery rates
Review product quality records	Verify the degree of Product development with Prime	How do we reduce lead-time?
Supply Chain Action Items		
STS	FTS	Prime
Site visits with FTS and Prime	Process map/flow with STS and Prime	Reusable containers as Kanban signal?
Possibility of managing sub-tier suppliers?	Certify STS	Identify communication issues

ASSIGN RESPONSIBILITY AND EXECUTE ON THE ACTION ITEMS

Creating action items and planning tasks to accomplish those action items is vital; however, it goes for naught if no one executes on that planning. As a participant commented, "it's only interesting until you get to the execution... actually putting it into place." Another senior manager stated that a lack of execution creates bad publicity and "squashes other initiatives." To increase the probability the agreed-to actions are implemented, someone in each company must be given responsibility to oversee the completion of the action items. Establishing lines of communication between firms are also necessary. Many of the actions items involve close coordination between companies.

> ***"Creating action items and planning tasks to accomplish those action items is vital; however, it goes for naught if no one executes on that planning."***

FOLLOW-UP

Instituting follow-up procedures is crucial for sustaining the initiatives. Milestones should be established and procedures for monitoring the progress should be developed. In addition, protocols for resolving unforeseen issues need to be established. If individuals are willing to move forward on implementing the action items, they must be able to see the fruits of their labor.

RESULTS FROM SCIW

After the workshop, the FTS and STS worked together to map their value-stream capabilities. Based on that work, several processes were altered to increase the efficiencies between the companies. According to one of the action items, the STS toured the FTS's facilities. Prior to this time the STS did not know how their part was used by the FTS. The tour also provided an opportunity for the STS to begin showing the FTS how a Lean enterprise would work to their mutual benefit.

The Prime-FTS-STS detailed supply chain mapping exercise, which was one of the action items, was completed several months after the workshop. This mapping exercise yielded some insights. In one case, the STS produced a welded assembly for the FTS. The existing supply chain had the FTS order, receive, and inspect the components on behalf of the STS, then send the inspected components down to the STS for assembly. The supply chain was changed so that the STS was certified to order, receive, and inspect these parts directly, without going through the FTS verification stage. This eliminated weeks from the overall lead-time.

Regarding another example, an FTS manager related:

> When they weld the two [housing] halves together there's an X-ray that gets done on that girthwell, and we always brought them in here and had the X-ray done at [our facility], and then…you know, you shipped the parts back again so you got this going from [their facility] to [our facility] to [them] to [us] and back and…we decided that was crazy to do that, so [they] found a supplier down there, an X-ray house, that could do that girthwell X-ray.

Beyond product interaction issues, the action items from the workshop lead to higher levels of trust and responsibility between the FTS and STS. For example, the FTS began working with the STS using a blanket purchase order, thus handing replenishment responsibility to the STS. In addition, the STS was able to elevate their product responsibility. This change reduced the friction from integrating the final assembly by shifting this total responsibility to one location.

"Beyond product interaction issues, the action items from the workshop lead to higher levels of trust and responsibility between the FTS and STS."

There were adjustments that had to occur between both sites to allow the STS to supply the entire component. The FTS Director of Materials recalled one of those adjustments on the FTS part,

> …[the STS] put their hands up for a while because they felt some of the cleaning [requirements], for instance, was a little too tough for them, they weren't quite ready for that. So that was one of the areas where we either did lose some requirement or we could have loosened the requirements and they eventually came around and said, okay, I think we can do that. But there were a number of technical interchanges between our guys and theirs to see…where we actually worked through, you know, what can we do, what can't we do.

The Prime and FTS also participated in some post-workshop activities, including more detailed value stream mapping and facility tours. One of the benefits of this interaction was introduction of some joint Lean/Six Sigma training across both facilities. All of these efforts were viewed as highly beneficial to the two companies, as the elusive *win-win* began to be realized. The managers realized that none of these improvements could have been realized without a direct dialogue for motivating and identifying these opportunities.

CONCLUSION

Coordinating the supply chain across organizational boundaries may be one of the most difficult aspects of supply chain management. Many firms simply are unaware of the fundamental dynamics of supply chains, but even those firms that are enlightened enough to understand these dynamics are often unable to realize inter-organizational coordination. Often the most effective supply chains have a dominating organization that sees the benefits of supply chain coordination and forces the rest of the supply chain to comply (i.e., Wal-Mart). Many supply chains, however, either do not have a dominant organization, or the dominating organization is unenlightened. In these instances, coordinating the supply chain is most difficult.

The methodology described in this paper is an effective means to develop inter-organizational coordination. To achieve supply chain coordination, companies must first be made aware of the fundamental dynamics of supply chains. Awareness can disengage the individual personalities within different organizations, and allow members of the supply chain to objectively view their value stream. Then, the individual organizations can define and measure the current state of their supply chain and finally agree to corrective actions that benefit the entire supply chain.

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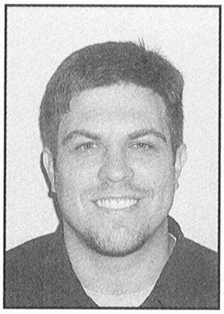

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ENDNOTES

1. The full version of the LESA is comprised of three operational modules (supplier integration, Lean production, and distribution integration), two organizational dynamics modules (management level, and front-line level), and one performance measurement module.

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