

**IMPLEMENTING NOVEL INVENTORY CONTROLS AND
WEIGHING THE COSTS AND BENEFITS OF SUPPLIER
MANAGED INVENTORY (SMI) IN A CONSOLIDATED
MANUFACTURING CENTER**

by

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B.A. Physics, University of Virginia, 2000

Submitted to the Sloan School of Management and the Department of Materials Science
and Engineering in partial fulfillment of the requirements for the degrees of

**Master of Business Administration
AND
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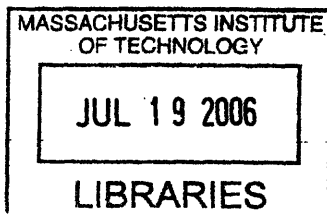
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Submitted to the Sloan School of Management and the Department of Materials Science and Engineering on May 10, 2006 in Partial Fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Materials Science and Engineering

ABSTRACT

The Largo manufacturing site of the Raytheon Company is a pure production facility with limited collocated design capabilities. All of the initial design and development engineering is done in four external sites – Marlborough, MA; St. Petersburg, FL; Towson, MD; and Ft. Wayne, IN – before final specifications are “thrown over the wall” to Largo for production. Because manufacturing is geographically sequestered there are numerous organizational and informational disconnects. Accountability is not easy with four distinct program management offices; each has equally distinct incentives and needs, and expects stellar results from the Largo production staff.

Materials normally account for approximately 75% of the total costs for a standard manufacturing operation. Largo is no different; however its material costs are often even higher than this benchmark for unique reasons. Difficulties arise for Largo in structuring its supply chain agreements because the four design sites have disparate material requirements and harbor unique supplier preferences. A salient symbol of the challenges faced by the site’s supply chain management group is the millions of dollars worth of inventory that sits in the vast factory storeroom. Current inventory floor accuracy is at an unacceptable level of 85.3%.

Getting rid of the inventory monster and its attendant problems is no trivial task, and certainly not one that could be accomplished in a six month LFM internship. But steps were taken to help get the ball rolling in the right direction and to generate some quick wins in the near term.

The first phase of the project involved the creation of a novel sourcing agreement with a key CCA supplier. The second phase involved optimizing the replenishment system to minimize material flow, implement pull, and increase material accountability. The final phase involved creation of a financial cost v. benefit model to standardize the site's methodology for making sourcing and partnering decisions in the future. All of these topics are discussed in this thesis as shown in the table of contents.

Overview of main internship project tasks:

The internship project was scoped to fit within the six and one half month allotted time period and was structured around the main problem points I have just briefly touched upon:

- 1. Identify optimal candidate supplier and part with potential for significant SMI cost savings.**
- 2. Structure SMI supplier partnership agreement.**
- 3. Implement and automate calculation of kanban system to control inventory**
- 4. Create SMI cost v. benefit tool to prioritize future projects according to expected returns on investment.**

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I also appreciate the tremendous assistance from the Largo Six Sigma group: Elizabeth Adkinson, Victoria Delesie, Jim Gaffney, Bob Milligan, John Petitgirard, Pete Pisasale, and Dave Scodellaro. The many "water cooler conversations" I had with each member expanded my viewpoint and helped me learn in depth knowledge that I would find nowhere else. I only hope that I was able to deliver enough value in return for the lessons you all have imparted upon me.

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Finally, and most importantly, I would like to thank my family and wife. Picking up roots every few months has been difficult over these last years, but after this experience is complete we will be able plant seeds that will be allowed to grow for a lifetime.

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1 Introduction

This introductory chapter begins with a broad description of the company's historical background and continues with a more detailed depiction of the specific business and location where the internship was focused. An outlook for the manufacturing site is then presented, followed by a glimpse of its recent organizational changes. The chapter finishes with an external view of the site's competitive position derived from a value chain analysis.

1.1 Background

The Raytheon Company was founded in 1922 under the name The American Appliance Company by former MIT professor Vannevar Bush, along with his former college roommate Laurence K. Marshall and fellow scientist Charles G. Smith.¹ Today Raytheon is the fourth largest U.S. defense contractor, after Lockheed Martin, Northrop Grumman, and Boeing, and manufactures systems for weapons and electronics.² However, the company's initial success was based upon a gaseous rectifier technology. Introduced in 1925, the gaseous rectifiers enabled consumers to use electricity to power their radios instead of more expensive batteries. The product generated over \$100 million in sales by 1926.

Not until WWII did Raytheon become involved in defense, when Britain needed to mass-produce magnetron tubes.³ The tubes were a core technology in the microwave radar systems used to detect Nazi raids. By the end of the war Raytheon was producing over 80% of all magnetron tubes used for defense purposes. Over the years, more key innovations followed. In 1947 the company introduced the Radarange, a precursor to the modern microwave oven, after scientist Percy Spencer discovered that a candy bar in his pocket would melt when he walked in front of a magnetron tube. Raytheon also designed

¹ Orientation at Raytheon Sites (OARS) Overview video, <http://oars-web.stp.us.ray.com/Presentations.asp>, accessed 14 December 2005.

² Raytheon Company profile, Vault Online Career Library, http://www.vault.com/cb/careerlib/careerlib_main.jsp?cl_page=58&product_id=1028, accessed 14 December 2005.

³ Raytheon Company profile, Vault Online Career Library, http://www.vault.com/cb/careerlib/careerlib_main.jsp?cl_page=58&product_id=1028, accessed 14 December 2005.

and manufactured the computer system that was responsible for guiding Apollo XI on its historic journey to the moon in 1969. More recently in the Gulf War of 1991, the company developed the Patriot missile – a weapon that played a key role in U.S. success on that tour.

The latter portion of the 1990s, with President Bill Clinton in office, was particularly difficult on the defense industry. The overall number of dominant defense firms dwindled as massive consolidation of the industry occurred. No stranger to mergers and acquisitions, Raytheon doled out \$12.5 billion in 1997 to acquire the large defense portions of Texas Instruments and Hughes Electronics.⁴ The company began to look outside the defense arena for new business and began to produce an increasing number of consumer items, including medical imaging and satellite communications products. After its bevy of acquisitions, Raytheon was over \$10 billion in debt and needed to streamline its artificially large conglomerate. A series of workforce reductions ensued, the largest of which was a 16% cutback of employees (approximately 14,000 jobs) in 1999. The company currently employs around 80,000 people.

The outset of the 21st century has been more prosperous for Raytheon, however. Business has increased in both overseas and domestic markets; highlights in each sector include a 2002 \$443 million contract with South Korea and Japan, and a 2004 \$1.3 billion contract with the U.S. Navy. Sales have steadily increased in recent years, up 8% in 2003, and climbing 12% in 2004 to \$20.2 billion.⁵ Diluted earnings per share (EPS) increased 7% in 2004 to \$0.95 per share.

1.2 Network Centric Systems

The Network Centric Systems (NCS) division is one of the six business units that compose Raytheon. The unit was birthed from a merger of one former Raytheon business, Command, Control and Communication Systems (C3S), with three external

⁴ Raytheon Company profile, Vault Online Career Library, http://www.vault.com/cb/careerlib/careerlib_main.jsp?cl_page=58&product_id=1028, accessed 14 December 2005.

⁵ SEC Form 10-K, Raytheon Company fiscal year ended 31 December 2004, <http://www.sec.gov/Archives/edgar/data/1047122/000119312505050699/d10k.htm>.

acquisitions, E-Systems, Texas Instruments' Defense Systems and Electronics business, and Hughes Aircraft's Defense Electronics. Now headquartered in McKinney, Texas NCS develops and produces mission solutions for networking, command and control, battlespace awareness, and air traffic management. With additional manufacturing sites in Goleta, CA, Waterloo, ON, and Largo, FL; the business sells to customers in the U.S. Armed Forces, the Department of Homeland Security, the Federal Aviation Administration, the National Guard, and foreign security forces. Seven departments operate within NCS: Air Space Management and Homeland Security, Command and Control Systems, Combat Systems, Integrated Communication Systems (ICS), Precision Technologies and Components, Thales-Raytheon Systems LLC, and Raytheon Systems Limited. In 2004 NCS had net sales of \$3.1 billion.⁶

The Largo, FL manufacturing site employs approximately 484 hourly and 335 salaried support personnel.⁷ The factory is a union shop, represented by the local 298 chapter of the International Union, United Automobile, Aerospace and Agricultural Implement Workers of America (UAW).⁸ Bargaining unit workers however only compose roughly half of the assembly, integration, and test (AIT) personnel on the floor. The balance of the employees are non-union.

Largo's product mix is as follows: cables, radios, telecommunications, and systems. Four general and non-descript categories, the business areas are not absolutely defined and some overlap exists between product groupings (e.g. cables are a product in themselves, but are also an integral part of systems). An example of a typical Largo product is the Secure Mobile Anti-Jam Reliable Tactical Terminal, or SMART-T, shown below. A testament to the site's ability to integrate complex products, this apparatus is basically a satellite dish assembly that is mounted atop a Humvee. The SMART-T provides mobile,

⁶ SEC Form 10-K, Raytheon Company fiscal year ended 31 December 2004, <http://www.sec.gov/Archives/edgar/data/1047122/000119312505050699/d10k.htm>.

⁷ "Welcome to Network Centric Systems Manufacturing Center" presentation, Dan Valeri, Operations Systems, Raytheon NCS Largo.

⁸ UAW and Florida UAW Local 298 websites, www.uaw.org and www.uawlocal298.org, accessed 15 July 2005.

worldwide, and secure voice and data communication to joint military forces. This system is representative of the intricate assembly required in many other Largo products.⁹



Figure 1: Raytheon NCS Largo SMART terminal mounted atop a Humvee

The center's core competencies are largely in the integration and testing of complex electronic systems. Largo is not a "true" manufacturing site in the sense that the majority of operations do not involve raw material inputs. Rather, it is an assembly facility that integrates numerous sub-assemblies into a final product, and then tests that product rigorously before shipment. The intellectual property associated with integrating disparate sub-assemblies - all manufactured with varying tolerances - is a primary competitive advantage for the site. In addition to integration, Largo's testing capability is second to none and sets it apart from competitors. For example, the large and expensive infrastructure required in the environmental stress screening (ESS) area is a significant barrier to entry for other companies, due mainly to the immense capital expenditure required for the purchase of these machines. ESS equipment is voluminous and cumbersome, and it subjects products to myriad thermal and vibrational tests to validate their efficacy in extreme environments.

A key aspect to understanding Largo's operations and its inherent production difficulties is the fact that Largo houses absolutely no initial design and development engineering. That is to say that all initial design and development capability comes from four sending

⁹ Conversation with Peter Pisasale, Six Sigma Expert, Raytheon NCS Largo, 15 July 2005.

sites; these design centers are located in Marlborough, MA; St. Petersburg, FL; Towson, MD; and Ft. Wayne, IN. Once the designs are complete, they are “thrown over the wall” to Largo for production.

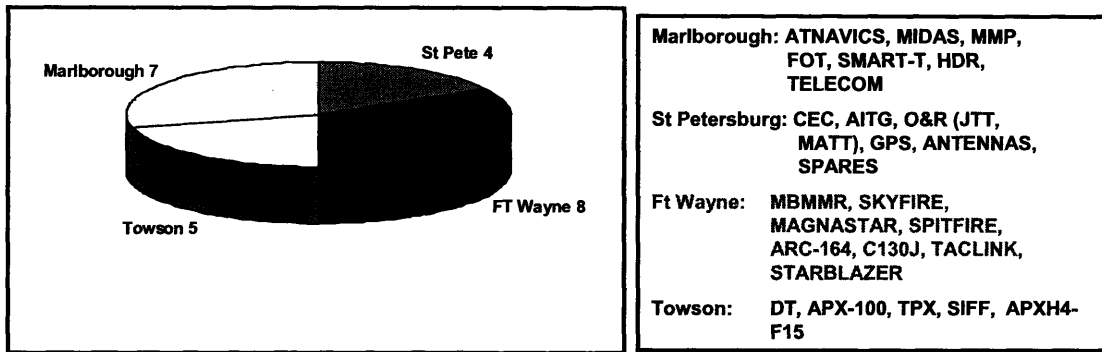


Figure 2: Four engineering sites send designs to NCS Largo for production of various product lines

1.3 Outlook: Largo Manufacturing Center & R6s™

Largo management’s stated goals for the fiscal year 2005 are sixfold:¹⁰

- Improve functional and program alignment and integration
- Improve supplier selection/quality and material management
- Improve responsibility, accountability and authority
- Improve competitiveness through lean manufacturing and benchmarking
- Upgrade critical skills and reduce dependence on external support
- Become more predictable in the customers’ eyes

The eventual target is to become a world-class manufacturing site, as defined by the Shingo Prize criteria. The Shingo Prize, known as the “Nobel Prize of manufacturing”, is an award given by the Utah State University’s College of Business each year to recognize

¹⁰ “Welcome to Network Centric Systems Manufacturing Center” presentation, Dan Valeri, Operations Systems, Raytheon NCS Largo.

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companies in North America who achieve best-in-class implementation of lean concepts.¹¹ Raytheon Integrated Defense Systems was the most recent internal division to win the award in September 2005.¹²

Attacking management's goal of lean implementation has been an ongoing effort at Largo since the turn of the millennium. Raytheon corporate identified lean manufacturing as a top priority in the late 1990s when the executive team devised a lean toolset and methodology to spread the idea throughout the organization. Supported by an external consortium of experts, an internal team led by former Raytheon CEO Dan Burnham explored a range of lean approaches. Seeking a solution unique to the Raytheon Company, the team created Raytheon Six Sigma™ (R6s) by benchmarking other similar corporate programs: the Texas Instruments Continuous Flow Manufacturing program, the Hughes Aircraft Agile program, the Motorola Six Sigma program, and the General Electric Six Sigma program. Ostensibly, there are four main goals of R6s:¹³

- Make customer success a strategic focus for the company
- Increase productivity
- Transform the culture
- Grow the business

To call employees to action, Raytheon leadership listed three key directives that all members of the organization must embrace in order for the new doctrine to be successful:

- **Customer Focus:** Customer satisfaction is the top priority.
Understand each customer's culture and needs. Focus on activities that add value to their products and eliminate those which do not.
Build lasting relationships and anticipate customer needs to achieve a competitive edge. Be the supplier of choice.

¹¹ Shingo Prize website, www.shingoprize.org, accessed 15 July 2005.

¹² Raytheon Shingo feature, <http://www.raytheon.com/feature/shingo/>, accessed 14 December 2005.

¹³ Raytheon R6S introduction, http://www.raytheon.com/about/r6s/r6s_what_is/index.html, accessed 14 December 2005.

- **Tools:** Identify the constraints and high-leverage opportunities through the business diagnostic process then combine the statistical process-analysis techniques of traditional Six Sigma with the lean manufacturing approach to eliminate waste and non-value-added activity. Provide the right analytical tools for each situation.
- **Culture:** Transform the corporate culture to embrace a process-improvement/measurement focus, teamwork and empowerment. Shift from valuing functional behavior to adopting a business/customer focus.

To complement the shift towards a lean mindset and encourage sustainability of Raytheon's lean vision over the long term, management added a set of run rules for lean implementation.¹⁴ Called the R6s process, the continuous cycle of improvement is arranged in a repeating wheel of change and involves six discrete steps illustrated and described below:¹⁵

¹⁴ Egan, Sarah, "Six Sigma Process Improvements and Sourcing Strategies Following Factory Fire", Massachusetts Institute of Technology, Leaders for Manufacturing thesis, June 2005.

¹⁵ Krishnan, Satish, "Driving a Lean Transformation Using a Six Sigma Improvement Process", Massachusetts Institute of Technology, Leaders for Manufacturing thesis, June 2004.

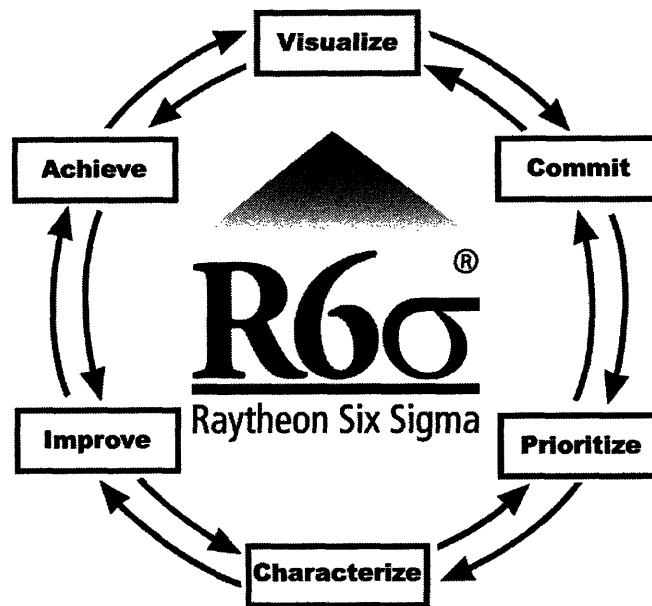


Figure 3: R6s is a six-step continuous wheel of change to drive process improvement

Step 1: Visualize the future state and establish a need, or burning platform, for change.

Step 2: Commit key stakeholders who can enable success.

Step 3: Prioritize tasks to ensure the efficient use of resources.

Step 4: Characterize the current state, perform a root cause analysis of desirable and undesirable effects, and then articulate a future state that incorporates solutions to underlying problems.

Step 5: Improve the system through implementing the proposed solution.

Step 6: Achieve success and document the benefits realized and lessons learned.

The Raytheon training goal is to have 100% of employees “specialist”, or green belt, certified by the close of fiscal year 2005.

1.4 R6s in Action: The Largo Organization

When I first arrived in Largo, there was a reorganization in process. The functional head of our R6s group was spearheading an effort to move the site towards a more synergistic value stream organization. A culture change was necessary to achieve two of

management's goals stated above: to properly align and integrate functions with operations, and to enhance both responsibility and accountability.

The radios business organization, a typical example of Largo's legacy structure, is shown below:¹⁶

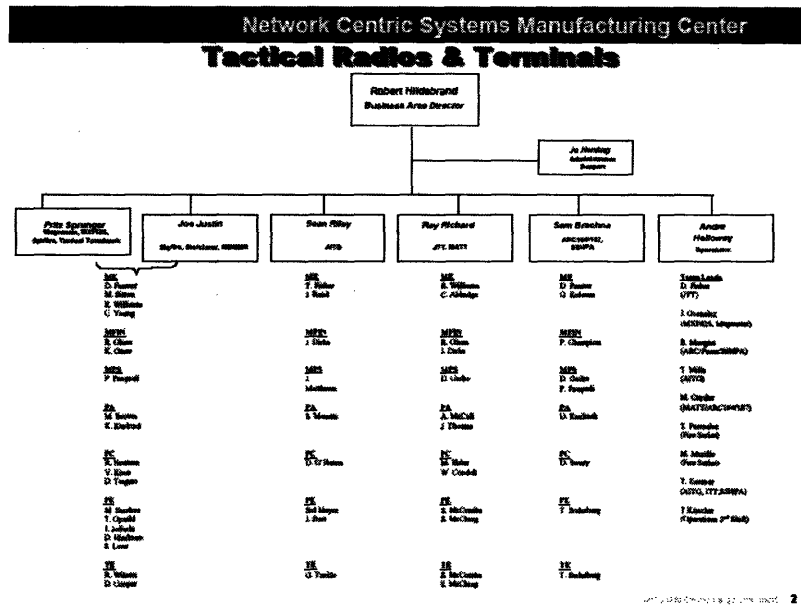


Figure 4: Largo's legacy organizational structure encouraged stovepipes

At the top of the chart sits the business area manager who oversees five product lines, each of which is vertically staffed with support personnel (shown in black). The product lines were not matrixed with accountability and existed primarily as siloed units. This approach to structuring Largo's organization abets sub-optimization and does not facilitate knowledge sharing. At its best, the organization had stovepipes of functionality with high performers married to a particular process; at its worst however there were troubled areas of underperformance where best practice sharing was inadequate as team members rarely rotated across functions and programs.

¹⁶ Raytheon NCS Largo Tactical Radios & Terminals organization chart, http://largo.stp.us.ray.com/largo_org.pdf, accessed June 2005.

By hosting a series of two-day business area lean “blitzes”, or short kaizen events, our R6s team acted as internal consultants and facilitated the site’s transition towards a leaner, matrixed value stream organization. Our main goals were:

- To implement cross-functional training and rotations
- To encourage knowledge sharing
- To fully matrix responsibility and accountability
- To unlock hidden process efficiencies and eliminate wasteful redundancy through value stream implementation

Involving floor personnel and allowing suggestions to percolate up from the bottom of the organization enabled us to better achieve buy-in for the new structure. During the blitzes, employees engaged in healthy debate about how the future state should look. Given general guideline constraints by the management on team sizes and purpose, the staff was able to develop a new structure for the business shown below.

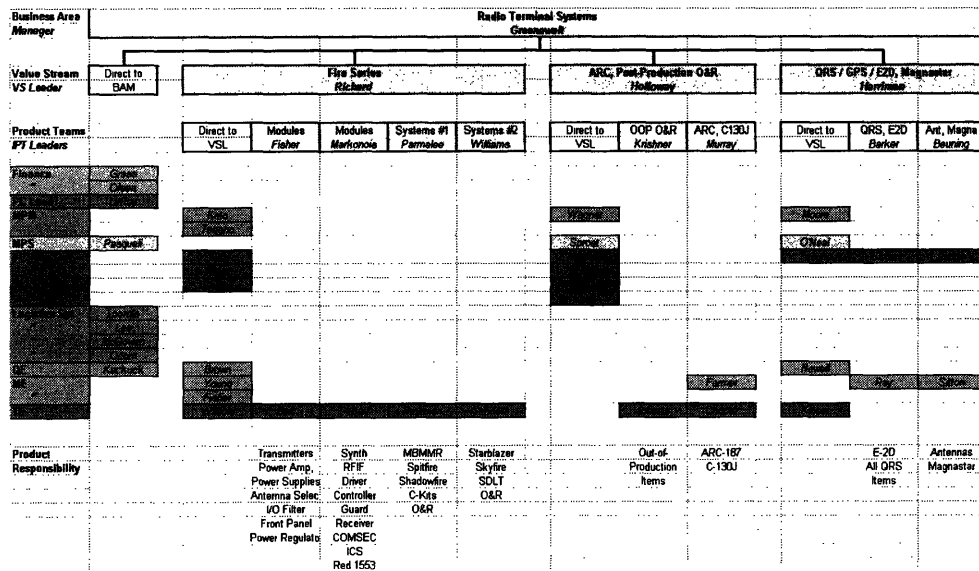


Figure 5: The new value stream organization and its cross-functional teams facilitate knowledge sharing across functions

The new structure was entirely created, bottom-up, by the production staff; the importance and implications of this fact cannot be overemphasized. Streamlining the former organization into three value streams (shown in green), the Largo staff was able to achieve each of the R6s goals and to create a more efficient future state. Cross-functional rotations were implemented as most positions carried an 18-month expiration before one would be pushed into a new role. Knowledge sharing among functions would be a side effect of the integrated product teams (IPTs) chartered with production. By sharing responsibility and focusing on a collective team effort, IPT members learn from each other and broaden everyone's purview. In addition, the new structure matrixes accountability between operations and functions by altering the performance review process. In the past, the functional homeroom had sole responsibility for evaluating a staff member's ability. For example, a finance member working on a particular product line was only accountable to his finance head – not the product line manager. At times, this behavior created conflicts of interest when production had certain requirements that did not necessarily mesh with those of the finance function. Under the reorganization, support personnel now became accountable to both production and function heads. Aligning more incentives behind the production process, the new arrangement more closely dovetailed the proper behavioral motivations with value-added activity.

1.5 From the Outside Looking In: the Largo Value Chain

Before one utilizes the Raytheon Six Sigma wheel of change, one must identify general areas of the business where opportunities may lie. In other words there must be a clearly defined project in order to begin the six-step process of improvement shown above. But how does one find opportunity? The Six Sigma Expert training manual outlines a methodology that starts with a *value chain analysis*. Raytheon defines a *value chain* as follows:¹⁷

A *value chain* is an “external look” at our competitive position. This approach is about focusing on the customer, but at a business design level. The value chain provides context for where the opportunities may be. It is

¹⁷ Raytheon Six Sigma: Expert Foundation 1, IV. Value Mapping, Raytheon Company, 2003.

essential that [one] understands [the] value chain, whether as part of a business diagnostic or as part of the validation work [one] will do, before [one] starts a project.

Clearly then the first step in any R6s effort begins with a value chain analysis. To accomplish this feat the first task I had was to outline the Largo value chain to help point the way towards a successful internship project. To construct the value chain I needed to know

- What the value chain output looks like.
- What questions I need to ask to get the data.
- Whom to talk to in order to get necessary data.

A complete value chain, as defined by R6s, is depicted below. The five elements – customer priorities, channels, offerings, inputs/raw materials, and assets/core competencies – provide the external glance at the site’s competitive position in the marketplace. By identifying each step accurately one will better understand the business drivers of success and be more attuned to outlining an impactful project.

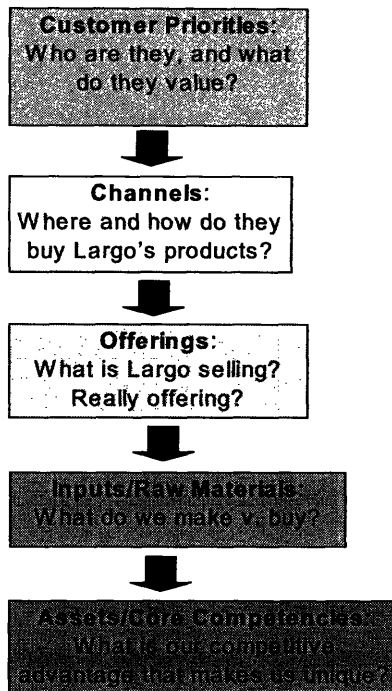


Figure 6: The R6s value chain framework reveals a business' drivers and competitive positions

To gain the necessary data to define the value chain, I drew from the Raytheon Expert training manual and developed the following list of questions to encompass all of the key points highlighted in the five steps above:

1. Who are your customers? Who are not?
2. What are you selling? What are you really offering?
3. How can your customer buy your goods?
4. What will you make? What will you buy?
5. What are your capabilities that - are unique in the industry? Are hard for the competition to copy? Valued by the customer?
6. What are your main concerns as the owner?
7. How does your business make money?
8. What makes your customers angry?
9. How do your customers make decisions? How do they differentiate among product offerings?

10. Who holds the power in the customer decision?

I posed these ten questions to the business area managers, functional group heads, and the site executive. Through these formal interviews over a period of three weeks, I gleaned the data necessary for constructing the current state Largo value chain. Three of the five steps in the value chain were easily defined by near unanimous feedback from the interviewees:¹⁸

- **Customer Priorities:** Customers are primarily external governmental entities, e.g. Department of Defense and the Federal Aviation Administration, and they look to Raytheon for a total value proposal including price, on-time delivery, technical competence, and past performance
- **Channels:** Customers receive Largo products primarily through one channel, the Federal Acquisition Regulations. This process includes, for example, requests for quotes (RFQ), etc.
- **Inputs/Raw Materials:** The raw materials that Largo buys are low-level assemblies; Largo makes high-level assemblies.

However, there was disagreement between the functional heads and the business area managers on the remaining two steps:

- **Offerings:** Does Largo offer customers the lowest cost production, or is production merely cost-effective?
- **Assets/Core Competencies:** Is Largo's core competence its intellectual property in the assembly-test-inspect process, or is it cost effectiveness (e.g. low-cost labor, a leased manufacturing facility)?

To resolve the last two points the entire group of interviewees and I convened to discuss the differing viewpoints. Members of both the functional and business groups expressed their opinions, and the meeting ended with both factions leaning towards *cost*

¹⁸ Data from interviews with Largo Leadership Team conducted between 6 June 2005 and 23 June 2005.

effectiveness as both Largo's primary customer offering and the site's core competency. Lowest cost production was nixed as Largo's primary customer offering as leaders cited examples of missed NCS bids due to excessive cost projections that were higher than competitors. Intellectual property was removed from possibility as Largo's core competence as stakeholders generally agreed that the site's assembly and test procedures could be copied by a competitor with adequate infrastructure. A final version of the Largo value chain, therefore, was cobbled together from the data and is illustrated below.

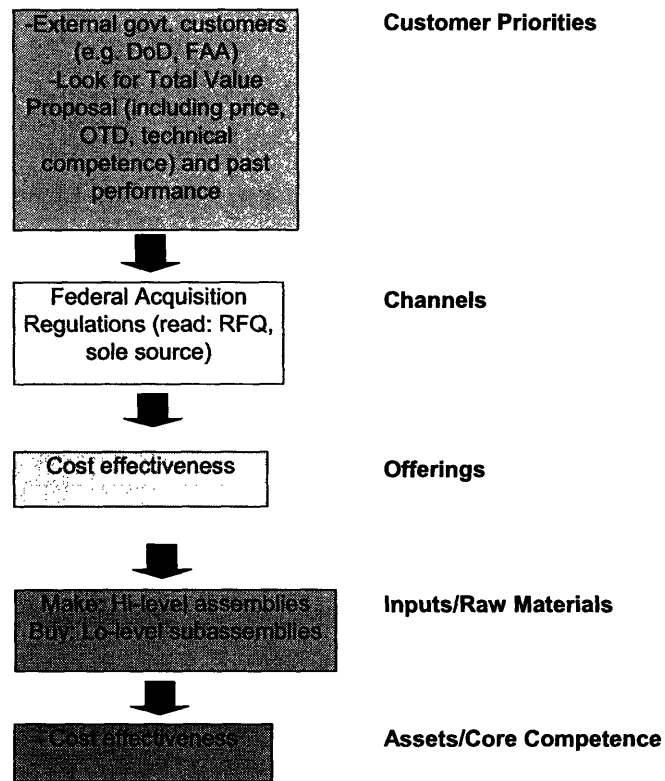


Figure 7: The Largo value chain highlights areas of opportunity for R6s

The conclusion I reached from the analysis is that *cost* and *speed* are the main business drivers for Largo's competitiveness in the marketplace. To wit I endeavored to tackle a project that would strategically reduce expenses and increase speed for the site. From a materials standpoint I would survey the facility to locate opportunities for waste removal, keeping in mind the goal to have drastic improvement on the business' bottom line within the internship time frame. As it turned out, I did not have to look far to find waste.

2 Visualize

This chapter begins with a presentation of the site's need for change in its inventory management process. The body of the chapter features discussion of material accountability, current replenishment rules, the push system, and methods being utilized at the site for calculation of production rates. Finishing the chapter is a survey and explanation of several inventory management schemes; breadman, supplier managed inventory (SMI), supplier owned inventory (SOI), and point of use (POU); followed by a literature review of the benefits of SMI.

2.1 The Burning Platform in Inventory

On average, 70-80% of manufacturing cost in any factory can be traced to materials and inventory. Largo is no different. Production cost plays heavily into the NCS competitive advantage to win new business. Though NCS as a whole has done extremely well in the last three years, it has also recently lost some key contract bids to competitors. Upper management signaled that two primary factors were to blame for NCS' shortfall: *cost* and *speed*. In some instances competitors' bids were 30% lower in cost, and 50% faster to full rate production than NCS bids.¹⁹ To the extent that NCS must reduce cost and become faster to market, Largo has been tasked as a site to lower its manufacturing costs and increase its inventory turns and cycle time. Inventory management is the site's "burning platform", or significant operational issue. Taken from the oil industry, the analogy compares critical organizational or operational issues to an oil rig fire where the issue is obvious and the need for change is imperative. Since the vast majority of production expenses are tied up in material, the supply chain represents an easy place to start attacking Largo's burning platform of cost and turn speed problems. As of June 2005, Largo's vast storeroom contained over \$126M of inventory. Largo's turns as of June 2005 were only 1.87, compared to a goal of 3.00 by the end of the year.²⁰

¹⁹ Colin Schottlaender, NCS President, speech during Largo site visit, 9 August 2005.

²⁰ Webplan data, provided by Bob Moutray, Senior Business Process Analyst, Raytheon NCS Largo, 11 August 2005.

A key contributor to inventory problems is the site's MRP system. A legacy hand-me-down from Raytheon's Fort Wayne, IN design center – the system was originally received from the former Hughes Company when it was acquired by Raytheon. Because this MRP system is aging and its flexibility is limited, mirroring process changes on the floor to system upgrades is a challenge. The difficulty in simultaneously changing physical and virtual processes in lockstep is illustrated in this thesis through the case of supplier-managed-inventory (SMI) material replenishment implementation.

2.2 Material Accountability

A recent internal audit of the manufacturing center affirmed NCS' suspicions that the facility had clear and present issues with its inventory management system.²¹ One identified issue of paramount importance was Largo's inability to track material inventory on the floor to a discrete location. Not being able to find material when needed leads to numerous other problems including losing inventory, expensive write-offs, and overpurchasing. These ailments in turn erode performance; for example, inventory turns are slower. Another implication of shoddy material accountability is its legal ramification. With the advent of Sarbanes-Oxley legislation in 2002, corporations are being held to higher audit standards and must have better internal controls for justification of all items on their balance sheet, including inventory. To that end Raytheon in general, and Largo in particular, are increasing their vigilance to become more accurate and transparent in their accounting reports. From the manufacturing side a large part of the improved reporting must come from more stringent material accountability.

One key problem with the inventory control system is its lack of granularity. Using a map analogy, let us assume that each part in inventory is analogous to a person with a discrete home address. In order to properly locate someone, one would need to know at least two pieces of information: street address and zip code. Taking this logic one step further, the inventory control system at Largo only sees zip codes – meaning that someone cannot know a part's specific discrete location at any given time in the factory

²¹ Internal audit, Raytheon Largo Supply Chain Assessment, 7 June 2005.

once it has been pulled out of stores. For SMI to work, suppliers must be know exactly where their parts are on our factory floor at all times. In this manner, they can accurately account for part usage in order to determine the proper replenishment rates. What is more, within a supplier-owned-inventory (SOI) scheme where the supplier still owns the material until we ship, they must have complete transparency into the whereabouts of their material in our factory since it is still on their accounting ledger. In this case, they are still financially responsible for the accountability of any material despite its not being in their factory.

In the future state we aim to achieve 100% material accountability and its attendant location granularity throughout the factory. This will require establishing “addresses” within our MRP system for discrete pull bins. That is to say that each bin on an operator’s workstation will have a distinct location coded both on the bin and in the MRP system. Currently, the bins are indistinguishable within the system. There are, however, “drop zones” around each product line that serve as a proxy for discrete locations. Consider the figure below. The product line shown is the APX-100 radio area of the factory.

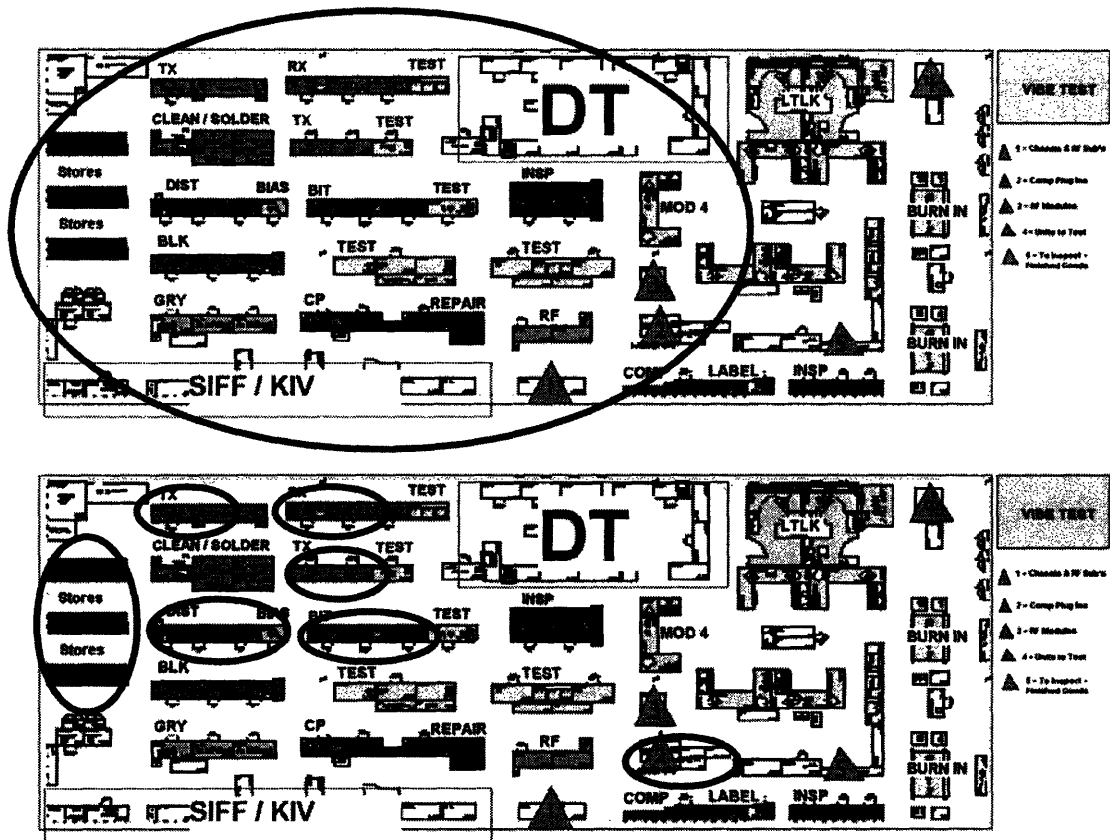


Figure 8: Legacy system tracking capability (above) lacks the granularity needed for SMI (below)

The red circles demarcate what the MRP system can see; the difference in granularity is striking. The top portion of the duplicate layouts represents the current state; the bottom is the future vision. In the top picture we see that material can only be tracked enough to tell whether it is in or out of the large circle. Inside the circle represents the “drop zone” where material can be identified to reside within the product line area. Outside of this region, however, material is assigned to the general storeroom. Thus in the current state there are two possible material locations: the general storeroom and the drop zone. The future state, represented by the bottom figure, shows a much more granular view. Here we see that each distinct subassembly workstation has its own discrete system location. This simple enhancement in location detail pays big dividends for the site’s overall material accountability. With the new system, we could locate material whether it be in stores, at a subassembly workcell, or in final assembly. Implementation of the scheme

involves not only virtual changes to the MRP system, but also physical changes in the bin system on the floor.

2.3 Replenishment Rules and the Push System

Another platform for change is the push system currently in use on the factory floor. A diagram of the process is shown below, highlighting the intensive manual intervention involved in the process.²²

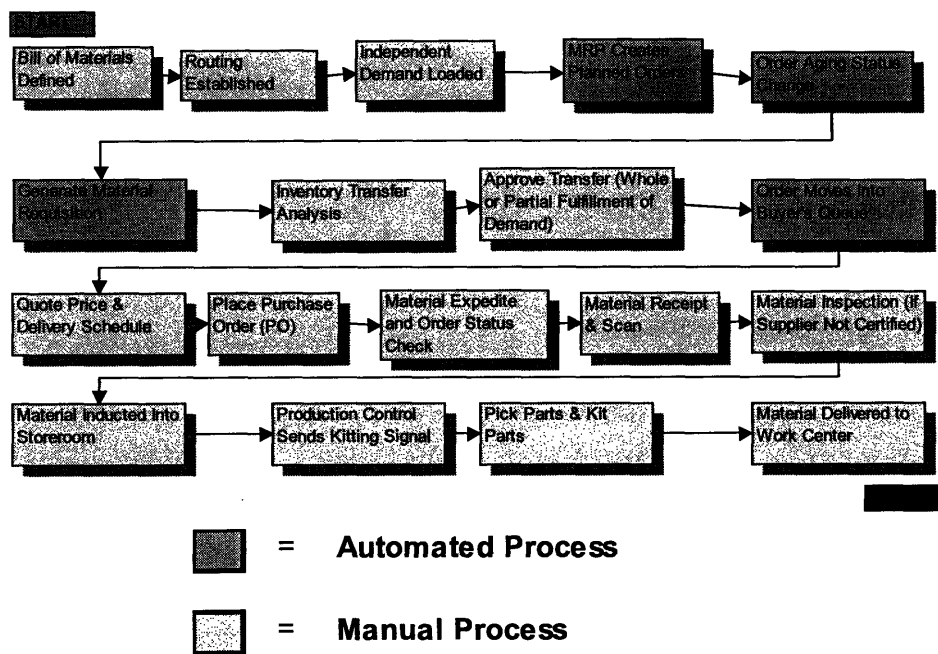


Figure 9: Current state push system to get parts into production involves significant manual intervention

Based upon a customer order, engineers define the requisite bill of materials and then a planner will load the demand for that product in the MRP system. The order will sit in MRP until the system recognizes, in conjunction with the production and supplier lead times, that it is time to open the order and begin the production process. Once the order is open, the procurement department is tasked with sourcing the required parts.

Procurement first looks into the bevy of internal inventory that may be available at any of the satellite Raytheon sites. If none can be transferred, then procurement must consider

²² Interview with Chett Gear, Raytheon NCS Largo Supply Chain Planning Manager, August 2005.

external price quotes and available delivery schedules before eventually placing a purchase order. When the material is delivered to Largo it is subjected to a series of manual operations including scanning, inspection, storeroom induction, and kitting before it is finally delivered to the appropriate workstation on the factory floor. It is important to note that the signal for material delivery to the floor is triggered by the MRP system lead times for production, and not cued by any sort of pull mechanism. The replenishment rules are thus simply stated: MRP decides when to push material onto the floor; the value stream does not signal when it is ready to pull more material into flow. To wit, this causes significant amounts of excess raw-in-process (RIP) inventory to reside on the floor at the beginning of the production line since most suppliers schedule their deliveries around our MRP system forecasts. As a result, oftentimes suppliers ship excess material to the site that Largo does not imminently need.

In addition to the waste generated by the push system, the excess of manual effort in the replenishment process is of concern. Much of the process, for example inventory transfer analysis, is either repetitive or non-value adding and can be automated. Other portions, like storeroom induction and kitting, can be altogether eliminated. An important step in helping Largo reduce wasteful activity in its replenishment process is partnering with the supplier to structure a process that enables both parties to experience mutual benefits from sharing information and resources.

2.4 Calculation of Build Rate

Customer demand in the defense industry can be euphemistically described as lumpy. Actual demand finds its way to the manufacturing floor as follows.²³

1. The Department of Defense (DOD) releases a request for proposal to a group of defense contractors, including Raytheon, who all then submit competing bids to win the business.

²³ Conversations with Jay Walsh, R6S Senior Manager, Raytheon NCS Largo, 9 August 2005, and John Petitgirard, R6S Expert, Raytheon NCS Largo, 11 August 2005, and Dan Valeri, Manager Operations Systems, Raytheon NCS Largo, 15 December 2005.

2. The DOD awards the Raytheon Company a contract with defined dates of delivery and product specifications.
3. Raytheon decides which of its businesses and facilities are awarded the contract's design and production.
4. The program management office of the winning business is notified and passes demand requirements onto its manufacturing center.
5. The master scheduling department takes the contract demand and loads it into MRP, trying to level the takt rate as much as possible.
6. The process controller on the floor receives the MRP demand report and monitors the build rate to ensure that production is on pace with demand.

To visualize the lumpiness of consumer demand, let us consider the following two figures.²⁴ The first shows how contract demand for a sample Largo product line changes per month over a 16-month period. This data stems from completion of the second step in the list above. The second graph shows how the master scheduling department, after receiving the contract demand, loads a less lumpy version of demand into the MRP system. This data results from completion of the fifth step in the above list.

²⁴ Raytheon NCS Largo "Long Look" demand data for sample product line, 25 August 2005. The numbers have been disguised but the trends remain constant.

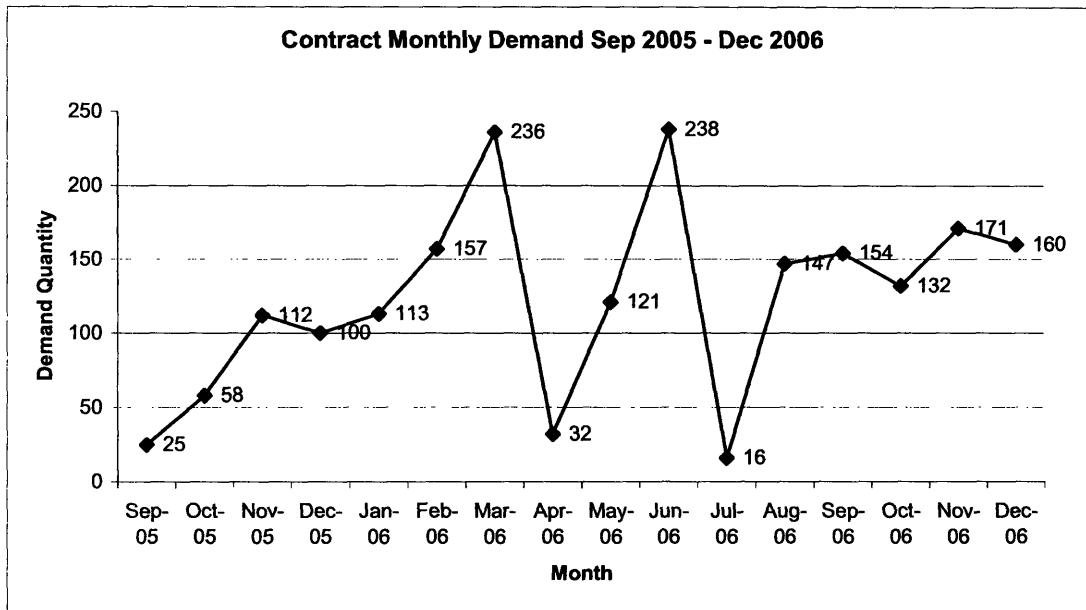


Figure 10: Customer demand is extremely volatile

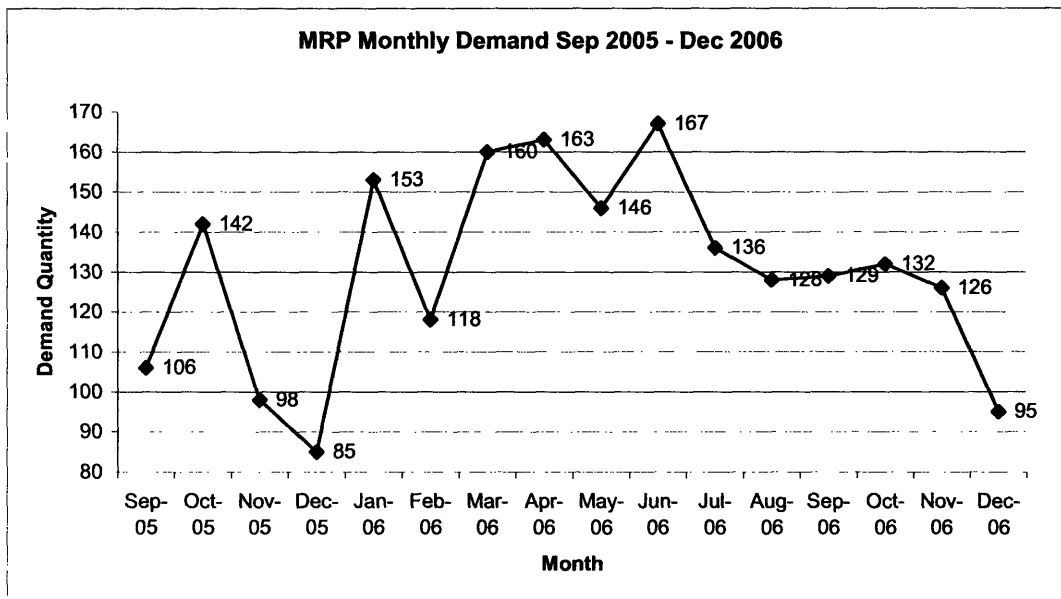


Figure 11: Largo MRP system demand is not level-loaded, though it is less lumpy than customer demand

From these data it is easy to calculate that the average monthly swing in contract demand is 117.8%, and the average monthly swing in MRP demand is 20.0%. Clearly, the master scheduling department does well to level the contract demand despite the fact that

production still has significant lumps that must be taken into account when daily build rates are established.

MRP provides the floor personnel with a monthly build requirement. The system does not dictate daily or weekly takt, but releases shop orders to the floor when the order's production lead time is equal to the remaining manufacturing days before shipment. Since these shipments are mostly bulk orders, for example when a customer demands delivery of 15 radios on a particular date, this means that shop orders are also released to the floor in bulk – promoting batch building behavior.

The manufacturing manager of the product line figures the daily build rate by a simple back-of-the-envelope calculation, an example of which is shown in the following figure.

<u>Daily Build Rate Calculation</u>	
Units to ship this month:	60
Available manufacturing days this month:	20
Daily build rate = units / # of days	3

Figure 12: The monthly calculation yields a build rate based upon anecdotal, not system, data

Insofar as manufacturing lead times are taken into account, the calculation relies on anecdotal lead times figured by the floor personnel. Though the personnel have a wealth of experience with the production and provide reasonable estimates of the cycle times, their views are not wholly accurate and are not based upon the actual system lead times calculated from historical build data. The daily build rate, as calculated above, is thus a best guess figure that is “backed into” based upon monthly shipments.

In the future state, we seek to use system takt rate data that is 100% accurate. Fortunately, Largo has a system named Webplan that automatically meshes MRP shipment demands with manufacturing lead times. It is through this system that one can access monthly material pull rates. In essence, the system can tell floor personnel when they should pull material into production in order to meet product shipment dates. In this

manner the production takt rate can be set straight from the system data, and not “backed into” via monthly arithmetic from the floor personnel.

To the extent that we have now outlined Largo’s challenges in the areas of material accountability, replenishment rules, its push system, and the calculation of daily takt rates, we must begin to look for ways to ameliorate the inventory situation by considering disparate replenishment scenarios. With the future state in mind, the next section will introduce and discuss alternative inventory management options. The underlying goal behind the discourse and literature review is to find the inventory management solution that will help Largo bridge its current state to its future vision.

2.5 A Review of Inventory Management Schemes

This section will briefly review a few key inventory management systems. A discussion, including a literature review, of the relative advantages and disadvantages of each scheme follows. Finally, the applicability of particular inventory management schemes to Raytheon Largo concludes the chapter.

2.5.1 Breadman Replenishment

Breadman replenishment schemes are a specific application of kanban, used in coordinating vendor replenishment activities.²⁵ In making bread or other route type deliveries, the deliveryman typically arrives at the customer's location and fills a designated container or storage location with product. The size of the order is not specified on an ongoing basis, nor does the customer even specify requirements for each individual delivery. Instead the supplier assumes the responsibility for quantifying the need against a prearranged set of rules, manually generating a list of those inventory needs, and delivering the requisite quantity to the customer.

²⁵ APICS Dictionary, Eleventh Edition, APICS, Alexandria, VA, 2005.



Figure 13: Breadman delivery schemes are common in the jugged water industry

The jugged water industry commonly uses a breadman delivery scheme. At regular intervals a deliveryman, as pictured above, physically checks the inventory of water at particular locations and replenishes it as necessary.²⁶

2.5.2 Supplier Managed Inventory (SMI)

Sometimes termed as vendor managed inventory, SMI is the practice of retailers making suppliers/distributors responsible for:

- Generating purchase orders (i.e. determining order size and timing) and,
- Maintaining the retailer's inventory (e.g. raw-in-process, RIP) levels, usually based on point-of-sale and inventory data.

Its goal is to increase retail inventory turns and reduce stock outs. It may or may not involve consignment of inventory (supplier ownership of the inventory located at the retailer).²⁷

There is a big difference in whether a purchase order is generated according to inventory data, or according to point-of-sale. Normally, MRP systems track inventory data and not sales. Thus even if the supplier has access to a customer's MRP, customer demand is generated by decreased inventory levels and not by end user purchases. This may lead to

²⁶ <http://images.google.com>

²⁷ Vitasek, Kate, Supply Chain Visions dictionary, <http://www.cscmp.org/Downloads/Resources/glossary03.pdf>, Bellevue, Washington, accessed 22 August 2005.

large variation in WIP levels on the floor and is not truly lean. A true pull system allows the supplier to see point-of-sale data, so he can generate customer demand based on end user purchases; this allows the end users to pull material all the way through the value stream. In other words, theoretically speaking, demand should be driven by cash register receipts, not inventory stock-outs.

A key characteristic that distinguishes a breadman scheme from a standard SMI scheme is that the breadman must manually check inventory levels by physically visiting each bin to see which parts are needed. An SMI scheme involves transparency of integrated systems between the supplier and the customer. Therefore, the supplier can virtually monitor inventory data from a distance and supply the customer as needed.

2.5.3 Supplier Owned Inventory (SOI)

SOI is nearly identical to SMI described above; the only key difference between the two approaches is the structuring of the consignment agreement. In SMI the supplier typically owns the material inventory until the time the parts are actually pulled from storage to be consumed by the factory. Thus when a material handler delivers parts to the assembly line, ownership is transferred to the manufacturer. In SOI however the point at which ownership transfers to the manufacturer is product shipment.²⁸ Therefore the supplier bears the expense of the material through production until it has completed final assembly and is packaged and shipped.

In practice this type of supplier-manufacturer agreement is difficult to negotiate and maintain. Profound trust must be inherent in the relationship. Also typical in SOI are a commoditized product for which there is a slew of available suppliers (and thus heated competition), and a relatively large manufacturer who has broad negotiating leverage to structure an agreement. For their part, suppliers normally do not want to bear the financial burden of manufacturers' process flaws that may force excess expense by scrapping material. To mitigate the costs of scrap, high first-pass yields are necessary to

²⁸ Vitasek, Kate, Supply Chain Visions dictionary, <http://www.cscmp.org/Downloads/Resources/glossary03.pdf>, Bellevue, Washington, accessed 22 August 2005.

ensure efficient processing of material. At times such high yields make the SOI relationship hard to maintain for manufacturers with complex production operations. The trust between the two parties can quickly sour if the supplier feels he is unjustly burdened through no fault of his own by the process inefficiencies of the manufacturer.

2.5.4 Point of Use (POU) Inventory Management

POU is simply any inventory management scheme where material used in production processes is physically stored where it is consumed.²⁹ This concept can be used in conjunction with any of the aforementioned management arrangements: SMI, SOI, or breadman. Most factories feature some level of material inventory at work cells. After all, assembly operators must have enough work in process (WIP) to keep production leveled and efficient. More often though, these same factories feature enormous stores of inventory in another location, whether it be a centralized storeroom or more localized material supermarkets. A pure POU scheme obviates the need for secondary material storage beyond what is physically kept at the workstation. That is to say that the only storerooms or supermarkets of material in the factory are the bins from which the assembly operators take the parts they need.

Current world-class manufacturers almost always realize the patent benefits of POU through coupling it with SMI. Suppliers are thus able to virtually monitor the production levels through a transparent MRP system and are required to deliver material at regular intervals directly to the POU on the floor. Simplified factory logistics and workstation accessibility must be a feature in any factory that implements POU. One can imagine a large factory with multiple vendors delivering a variety of material to disparate floor locations. Congested intra-factory traffic can adversely affect even the best world-class production operations, causing a spike in the occurrence of safety problems and stock-out issues. For these reasons strategic factory layout is paramount to the streamlining of POU.

²⁹ Vitasek, Kate, Supply Chain Visions dictionary, <http://www.cscmp.org/Downloads/Resources/glossary03.pdf>, Bellevue, Washington, accessed 22 August 2005.

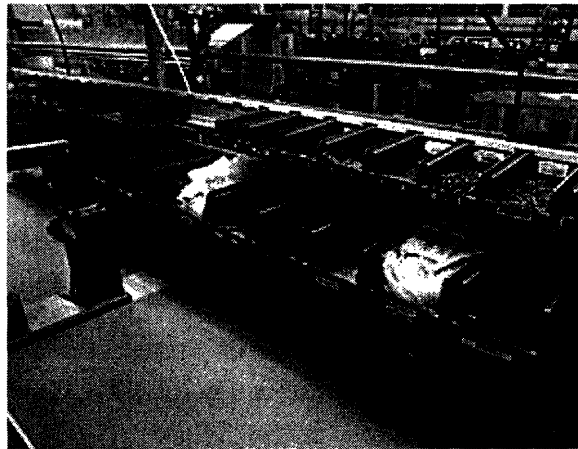


Figure 14: POU workstation bins limit stored inventory and enhance visual management of quantities

The figure above illustrates the POU management of inventory at a fastener plant.³⁰ The manufacturer has no other stores of material besides what is contained in the part bins at the workstation.

2.6 Literature Review: Benefits of SMI

In the latter half of the 1990s, Clark and Hammond conducted a broad study of SMI and its benefits in the grocery industry.³¹ A sector known for its razor-thin margins and high dependence on inventory management performance, the grocery industry serves as a good litmus test for the feasibility of SMI in other business models. The pair of researchers studied various modes of replenishment processes that were coupled with electronic data interchange (EDI). EDI is defined as the computer-to-computer exchange of information between suppliers and manufacturers such as purchase orders and invoices. Testing the hypothesis that EDI alone does not yield significant improvement in inventory management, Clark and Hammond demonstrated that performance improves more than an order of magnitude when EDI is used in conjunction with a continuous replenishment process (CRP) such as SMI. On average, retailers utilizing EDI and some form of CRP increased inventory turns by 50-100%. The process efficiencies were realized by virtually eliminating purchase orders, minimizing human intervention, and

³⁰ <http://images.google.com>

³¹ Clark, Theodore, and Hammond, Janice, "Reengineering Channel Reordering Processes to Improve Total Supply Chain Performance", *Production and Operations Management*, Vol. 6, No. 3, Fall 1997.

more closely linking supplier shipments with end user demand. The researchers also uncovered the fact that “an essential component of the CRP process is the implementation of an effective demand forecasting model in the CRP system to use sales data to determine shipment volumes”.³² To the extent that forecasting is paramount to a CRP system, the defense industry is particularly well suited for such process reengineering since most of the customer demand is fixed and known well in advance.

Clark and Hammond expound upon the observation that EDI alone does not unearth hidden efficiencies. While the electronic information flow between computers is instantaneous it does not provide a large time advantage over existing methods of communication, such as fax machines. Verification of this assertion was realized through comparison of surveyed responses from 49 large retailers and manufacturers who have adopted EDI and/or CRP. Participants included large well-known companies like Proctor & Gamble, Hannaford Brothers, and Wal-Mart, and the statistical analyses are shown below.³³

³² Clark, Theodore, and Hammond, Janice, “Reengineering Channel Reordering Processes to Improve Total Supply Chain Performance”, *Production and Operations Management*, Vol. 6, No. 3, Fall 1997, p. 249.

³³ Clark, Theodore, and Hammond, Janice, “Reengineering Channel Reordering Processes to Improve Total Supply Chain Performance”, *Production and Operations Management*, Vol. 6, No. 3, Fall 1997, p. 260.

Increase in annual inventory turns:				
	EDI Adoption		CRP Adoption	
	Mean	SE Mean	Mean	SE Mean
All Retailers	0.53	0.28	8.4	3.0
Low or no CRP	0.12	0.12	1.2	1.1
High CRP only	0.82	0.46	13.0	4.4

Decrease in stockouts:				
	EDI Adoption		CRP Adoption	
	Mean	SE Mean	Mean	SE Mean
All Retailers	0.48	0.22	1.6	0.33
Low or no CRP	0.19	0.13	0.86	0.40
High CRP only	0.69	0.36	2.1	0.43

High CRP is defined as retailers with more than 5% of grocery product replenishment using CRP in 1993. Low or no CRP includes all retailers with 5% or less of grocery product replenishment using CRP in 1993.
 Note: The survey asked what change in inventory turns and stockouts resulted from adopting EDI ordering. For CRP, the survey asked what change in each resulted from switching from EDI ordering to CRP.

Figure 15: Results from the study suggest that EDI coupled with CRP increases inventory turns and decreases stockouts

These data attempt to illustrate what portion of a given performance improvement is due to EDI, and what is derived from CRP adoption. As shown, companies that assigned more than 5% of their products to continuous replenishment reported an increase in inventory turns of 0.82 due to adoption of EDI, and an increase in turns of 13.0 due to the adoption of CRP. Clarke and Hammond’s work suggests that novel inventory replenishment methods such as SMI can yield enormous advantages in efficient inventory management for firms tasked with overseeing material flow.

3 Commit

This third chapter covers many of the cultural and organizational aspects of the project. We begin by identifying relevant stakeholders and discussing methods for earning organization support, following with a literature review of the implications of trust and communication in SMI relationships. Finally methods of selling new inventory management concepts internally as well as the implications of a SMI cost v. benefit model are presented.

3.1 Defining Relevant Stakeholders and Earning Buy-in

Achieving cultural support for any change initiative is often a sticking point that hinders success. It is for this reason that Raytheon has placed “commit” as the second crucial stage on its Six Sigma wheel of change. First, one must identify which stakeholders are important to excel. Second, incentives must be put in place to drive the proper behavior from each key player. Finally, and perhaps most importantly, stakeholder relationships must be cultivated and continuously maintained to ensure the ongoing health of the new process.

In the course of such a short six-and-a-half-month internship, working on the cultural change facet of the project often takes the longest period of time. Therefore it is essential to begin soliciting buy-in as quickly as possible. Once the SMI implementation project was defined, I began the first “commit” step of identifying which stakeholders would be required for a successful internship. Three main groups were identified, with the attendant personnel that would need to contribute to the team’s success:

1. Site leadership team
 - a. Internship champion
 - b. Internship mentor
 - c. Business area manager
2. Supplier management
 - a. Supplier leadership
 - b. Supplier’s Largo liaison
3. Product line operations
 - a. Product line manager
 - b. Process controller
 - c. Procurement
 - d. Operators and material handlers
 - e. Six Sigma team

Within the Largo's site leadership team, the internship champion was the site executive, the internship mentor was the functional head of the Six Sigma group, and the business area manager was the head of a group of product lines within the factory. The supplier's management that needed to buy-in was the regional vice-president, and whoever would be responsible for Largo shipments as the supplier's liaison. The important stakeholders within our site's operations included the product line manager, the process controller responsible for material flow on the factory floor, the procurement person tasked with material sourcing, the Six Sigma team facilitating the project, and the operators and material handlers functioning in the new replenishment environment.

In order to learn how to frame the stakeholder commitments and properly incentivize the key players, a literature review was completed to assess lessons from past research and business cases that would be applicable to creating cultural change at Largo that would facilitate SMI implementation.

3.2 Literature Review: The Implications of Trust and Communication in Productive SMI Relationships

“One of the barriers to adoption of CRP by retailers has been an unwillingness to share information with manufacturers. The grocery channel has traditionally involved adversarial win-lose negotiations between retailers and manufacturers. Many retailers have been reluctant to develop the trust-based relationships with vendors that are necessary for sharing of data. They are only willing to share information if they perceive that the benefits of this information sharing offset the perceived risks involved”.³⁴

The sentiment above, taken from Clark and Hammond, articulates a concern that is common to all genres of operations. The veracity of the statement is consistent no matter whether one is considering the relationship between a manufacturer and a retailer, or

³⁴ Clark, Theodore, and Hammond, Janice, “Reengineering Channel Reordering Processes to Improve Total Supply Chain Performance”, *Production and Operations Management*, Vol. 6, No. 3, Fall 1997, p. 263.

whether the relationship is between a manufacturer and a supplier. Historically, the interface between these parties has been abrasive and hostile. Contractual relationships were most often short-term engagements that followed contentious negotiations. In recent years, however, the tide has turned. Lyons, et al conducted a study of modern buyer-supplier relationships and noticed some key departures from the traditional depiction of warring spouses.³⁵ Insofar as there were indications of new relationship trends, the team identified three major areas of evolution in buyer-supplier association:

- Supply base rationalization
- Longer-term contracts and relationships
- Acquisition of subassemblies rather than individual parts

Supply base rationalization involves drastically reducing the total number of suppliers to leave a core group of strategic supply chain partners. Dovetailing with the total base reduction are long-term contracts that solidify alliances with the remaining suppliers. Lyons, et al argue that manufacturers look for, and often receive, benefits from the relationships including cost reductions, increased quality levels, and shorter cycle times for production and delivery. Benefits must nonetheless be mutual for the engagement to be a win-win, and the advantages are not always easy to spot for the suppliers. To be sure, the long-term stability associated with multiyear contracts is a boon for suppliers. Lyons, et al show that suppliers benefit in other ways as well. In a study of the three domestic auto manufacturers, the researchers surveyed buyer-supplier relationships during a period where each car maker was reducing its overall supply base by one half. The long-term supplier partners that made the cut were examined to weigh the advantages of the novel arrangement, which are summarized below.³⁶

- Contract predictability
- More stable production and workforce

³⁵ Lyons, Thomas, et al, "Mixed Motive Marriages: What's Next for Buyer-Supplier Relations", *Sloan Management Review*, Spring 1990, 31, 3.

³⁶ Lyons, Thomas, et al, "Mixed Motive Marriages: What's Next for Buyer-Supplier Relations", *Sloan Management Review*, Spring 1990, 31, 3, p. 34.

- Buyer support
- More strategic decision making

Through information sharing with manufacturers, Lyons, et al showed that the automotive suppliers could more accurately predict contract schedules. Forecast precision trickled down other benefits such as leveled production and creating stable workforce staffing requirements. This synchronization of production schedules between the manufacturers and suppliers resulted in significant cost reductions. A final benefit described in the paper illustrates that suppliers could make increasingly strategic decisions for future growth. While not an obvious advantage at the outset of the new agreement, strategic decision making was made possible when suppliers had to expend fewer resources on tactical day-to-day decisions. Ray and Swanson also corroborate this point in the hospital industry, showing that more value-added activity occurred when suppliers and customers synchronized their business processes.³⁷ Time saved by eliminating purchase order placement and redundant fact checking was used for more beneficial purposes. Fire fighting, as it is called in the industry, became increasingly rare allowing suppliers to think ahead and make strategic plays to grow their business.

These benefits notwithstanding, there are potential risks for suppliers as well when they structure long-term engagements with manufacturers. Lyons, et al observed that some suppliers had decreased autonomy and experienced difficulties in information sharing.³⁸ Suppliers may experience decreased autonomy due the structure of the contractual agreement itself. Since most long-term supplier relationships necessitate there being a dedicated supplier representative who works full-time at the manufacturer's site, the supplier's organization will lose some operational resources. This loss is often temporary, however, and can be viewed as a short-term cost for a long-term relationship gain. Oftentimes when initial relational and production issues are resolved, the dedicated supplier representative is free to return to his home organization. Suppliers also

³⁷ Ray, Keli, and Swanson, Curt, "Supplier Managed Inventory: Schedule Sharing", *Hospital Material Management Quarterly*, May 1996, 17, 4, p. 51.

³⁸ Lyons, Thomas, et al, "Mixed Motive Marriages: What's Next for Buyer-Supplier Relations", *Sloan Management Review*, Spring 1990, 31, 3, p. 34-35.

experience difficulties in information sharing. Within the long-term partnership, open audits of financial records and production facilities are common. Historically, such confidential information would never be compromised and is thus difficult to share with manufacturers. Lyons, et al state that although they have never witnessed abuse of such sensitive information, suppliers' reluctance to provide complete transparency still exists. One supplier of GM expressed its concern as follows:

“Suppliers are concerned that intimate business information gathered by GM during on-site inspections of plants will result in price-slashing demands, loss of business for those faring badly on assessments, and technological advances being disclosed to competitors”.³⁹

At the core of the dilemma between manufacturers and suppliers lies trust - an issue that is fundamental to all relationships, not just those in manufacturing. While it cannot be magically created in a contract or easily obtained in the short term, trust can be built over time through honesty and earnest collaboration in business practices. Lucid communication facilitates improvement of the manufacturer-supplier interface and must be continuously monitored to ensure all parties are on the same footing.

3.3 Selling the SMI Concept Internally

At the outset of the “commit” phase, three stakeholder groups were identified as crucial to the success of the SMI implementation: Largo site leadership, product line operations, and the supplier's management. The next step was to determine each group's careabouts, or what concerns them most on a daily basis. Pinning down what matters to disparate groups is analogous to identifying in which currency different banks trade. Certain issues that are meaningless to one group can be incredibly important to another. Following the banking analogy, a safe full of dollars is worthless to a bank that only trades in Chinese yuan. On the other hand, the safe would be extremely valuable to the U.S. Treasury. At

³⁹ “Suppliers Fear GM Scrutiny”, *Crain's Detroit Business*, 28 September – 4 October 1987, Vol. 3, p.1, cited in Lyons, Thomas, et al, “Mixed Motive Marriages: What's Next for Buyer-Supplier Relations”, *Sloan Management Review*, Spring 1990, 31, 3, p. 34.

Largo, pairing the right “currency”, or careabout, with the appropriate group enhances our project’s chance of success.

By knowing what lies within a particular stakeholder’s purview, we can tailor incentives that will drive constructive behavior. In addition we can predict who will be affected when certain obstacles occur. As an example let us consider the scenario where SMI implementation *increases the cost per part* for a particular product line but *decreases overall site overhead rate* by reducing wasteful activity. Our first stakeholder group, the Largo site leadership, would be quite pleased with this result. From their point of view at the holistic site level, overall costs went down and performance was enhanced. The product line operations management would be displeased with the new SMI arrangement. Though the site’s costs as a whole are now less, the incoming material costs for their product line have increased. From the vantage point of the product line, the higher cost erodes their performance and makes them look less efficient than they were before SMI. The product line personnel might therefore conclude that SMI is not beneficial. Our final group, the supplier management team, could have mixed feelings about the new SMI arrangement. While their deliveries are better synchronized with Largo’s production under SMI, they may not like the open audits of their financial outlook and production facilities. The supplier might also have a lukewarm sentiment towards SMI.

Though the stylized example presented above is overly simplified, its underlying message rings true: one must make sure all stakeholders understand the benefit of a new approach in order to have lasting buy-in and success. At Largo, proselytizing the product line and supplier personnel with the benefits of SMI could not begin without first getting the site leadership team on board. Fortunately, this was an easy task. The site executive, having recently relocated from another Raytheon site that employed SMI, immediately saw the strategic advantages of the new replenishment technique. Having his support was like having a platinum credit card in our pocket. To achieve subsequent buy-in from other leadership members we simply needed to “show” our platinum card, or illustrate the top executive’s support, to have our idea accepted. The other leaders recognized that the

project was fully backed by an edict directly from the site executive, and understood its implicit benefits.

The supplier's management was eager to listen to the SMI discussion. Their initial motivation was to participate in order to maintain its share of Largo's business. However, our team realized that that motivation alone would not endure a sustainable relationship over the long term. We had to structure the agreement such that the supplier would gain palpable benefits as well. From reading the research completed by Lyons, et al, Clarke and Hammond, and others we were able to gain insight into how best to incorporate the supplier's concerns into a contract that would be mutually beneficial. We needed to address concerns about information sharing, production predictability, and potential problem resolution.

The final group to whom we needed to sell the idea was the product line management. This group had the most knowledge of the underlying process flow and was composed of subject matter experts on the particular product. They knew the specifics better than anyone else in the plant, and would therefore be the hardest to convince. Moreover, they were the most important group to persuade because they would be the stewards of the SMI process going forward. No longer would a platinum card from the site executive carry much clout; these people spoke in terms of part numbers, shipment dates, cycle times, and dollarized costs. Long-term strategy mattered less than immediate performance and cost savings. Our team would literally have to "show them the money", or illustrate the bottom line benefit, to achieve buy-in.

3.4 Implications of the SMI Cost v. Benefit Model

To dollarize the benefit of the SMI project and to win over key stakeholders, we needed a cost v. benefit tool that would attempt to accurately estimate the potential impact of our effort. Unfortunately such a cost v. benefit estimation model did not exist at Raytheon. Hence, we had to sculpt one ourselves. A large effort to be sure, creating a cost v. benefit model from scratch would involve identifying activities affected by the SMI process and populating the model with labor rates and other costs in order to estimate the savings

generated from our project. Our Largo R6s team's limited resources would be totally consumed by such a large undertaking, and we simply could not concurrently forge ahead with an SMI implementation while being tasked with creating a novel cost v. benefit tool.

Fortuitously for our team SMI was a popular idea throughout Raytheon, and a variety of sites were also working on its implementation. Multiple sites could thus benefit from the development of an SMI cost v. benefit tool that was heretofore unavailable as a resource. Our best chance to rapidly construct the model was to combine forces with sister sites and work collaboratively to quickly build the tool we all needed. Working with a larger cross-functional team would also abet standardization of the tool so that it may be useful to a range of business units, not just Largo NCS. As a result we formed a team tasked with the tool's development that included members from Raytheon's NCS, Integrated Defense Systems, Raytheon Aircraft, and Space and Airborne Systems businesses.

4 Prioritize

This chapter begins with a discussion of how to best prioritize SMI implementation projects within a factory by choosing the right inventory part and supplier, continues with a literature review of effective SOI partnerships in the real world, and finishes by touching upon effective tactics that form mutually beneficial manufacturer-supplier relationships while evolving counterproductive, legacy bureaucratic culture towards becoming more efficient and data-driven.

4.1 Choosing the Best Inventory Part and Supplier Candidate for SMI

After identifying the necessary stakeholders and beginning a grassroots campaign to achieve proper buy-in, our next task was to prioritize the parameters of the SMI project. More specifically it was time to decide what piecepart would go onto SMI replenishment first, and which supplier was going to provide us with that part. Our aim was to prove the SMI concept and thereupon build a templated approach to SMI that could be utilized throughout the factory in future implementations. We had to have a quick win with salient unmistakable benefits; failure was not an option. In choosing what part and which

supplier we wanted to move into SMI replenishment, we needed to answer key questions by considering three main points:

- **Bottom Line Benefit**
 - What percentage of our future demand dollars does the part represent?
 - How much can we save with the SMI process?
- **Supplier Outlook**
 - Is the demand with this supplier consistent? Or will it disappear in the coming months?
 - How important is this supplier to our strategic production outlook?
 - How resistant is this supplier to forming an SMI partnership?
- **Affected Activities / Behavioral Changes**
 - What portion of our parts does this supplier control?
 - How many Stock Keeping Units (SKU) will be affected?

A keen eye will notice that these three points exactly dovetail with the valued currency of each of the three key stakeholder groups previously identified. The bottom line benefit addresses the monetary payoff concerns of the product line management, the strategic supplier outlook covers many information exchange issues for the supplier partner, and all three points speak to the site leadership's goals of increasing productivity and transforming culture. If chosen correctly and implemented successfully, our candidate SMI supplier and pieceparts for the first SMI project would prove to all involved stakeholders that the effort is worthwhile for them and should be spread across the organization at large.

Our goal for maximizing the project's bottom line benefit would be achieved by selecting high-dollar parts with a strong and healthy demand outlook. As has already been stated, the Largo site held approximately \$126M of inventory overall. SMI in general, and our project in particular, would therefore be most effective if we were able to attack as large a chunk as possible of that humongous figure. Targeting an appreciable portion of the inventory would require removing large dollar amounts of surplus material from the

storeroom and moving those dollars towards a leaner SMI replenishment process. Delving deeper into the inventory problem, however, reveals that all dollars are not created equal. That is to say, removing one dollar's worth of A parts has vastly different project implications than removing one dollar's worth of C parts does.

To understand the distinction, let us first review the ABC part classification scheme. The APICS dictionary concisely defines the idea as follows.

“ABC classification - the classification of a group of items in decreasing order of annual dollar volume (price multiplied by projected volume) or other criteria. This array is then split into three classes, called A, B, and C. The A group usually represents 10% to 20% by number of items and 50% to 70% by projected dollar volume. The next grouping, B, usually represents about 20% of the items and about 20% of the dollar volume. The C class contains 60% to 70% of the items and represents about 10% to 30% of the dollar volume. The ABC principle states that effort and money can be saved through applying looser controls to the low-dollar-volume class items than will be applied to high-dollar-volume class items.”⁴⁰

Following the logic above, we see that one dollar's worth of C parts represents significantly more part volume than a dollar's worth of A parts. Therefore, the activity required to manage a higher volume per dollar of C parts (receiving, tracking, inspecting, etc) is more labor intensive per dollar than A parts. Since changing activity requires changing human behavior, often the most time-consuming task on any project, and given the fact that our team had a goal to generate a decisive quick win in less than six months, we therefore focused our attention on SMI candidate A parts. Not only would the A parts represent more demand dollars per part, but they also would require the least change in human activity per unit of all the ABC parts. We could thus quickly gain monetary benefit without encountering large cultural obstacles.

⁴⁰ APICS Dictionary, Eleventh Edition, APICS, Alexandria, VA, 2005.

Targeting the A parts, I analyzed the site's demand outlook to determine which items had the highest future incoming dollar volume and number of SKUs. Again, aiming for large dollar volume is beneficial because it allows us to implement lean controls on inventory management for our most expensive parts with the steadiest volume. Minimizing excess inventory on those parts would show the most drastic reduction in our surplus inventory dollars. SKU count, on the other hand, is a good proxy for manufacturing activity. As stressed above, the more volume of disparate parts we have entering our site, the more human activity it takes to effectively manage that inventory. I looked for a part category that showed high future demand and a relatively low SKU count. With the help of Largo's inventory system data the task was made easy by sorting the site's part demand categories first by descending dollar value, then by ascending SKU volume. The chart below illustrates the methodology used.

Part Category Potential for SMI Implementation

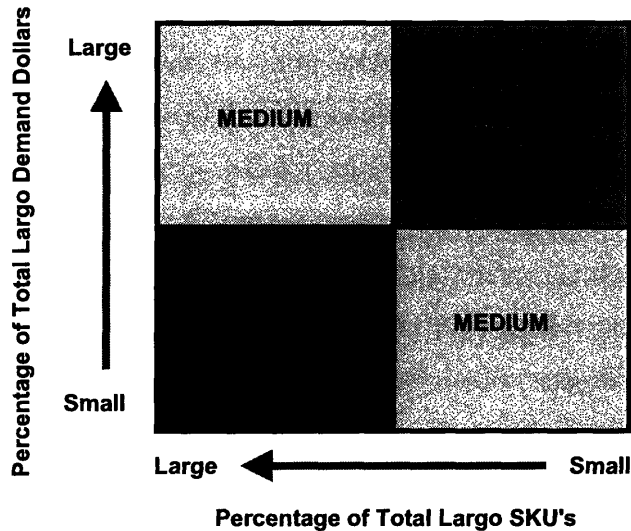


Figure 16: Framework identifies high-dollar inventory that does not require significant touch time per dollar

Demand Percentage v. Stock Keeping Unit Percentage for Largo Parts

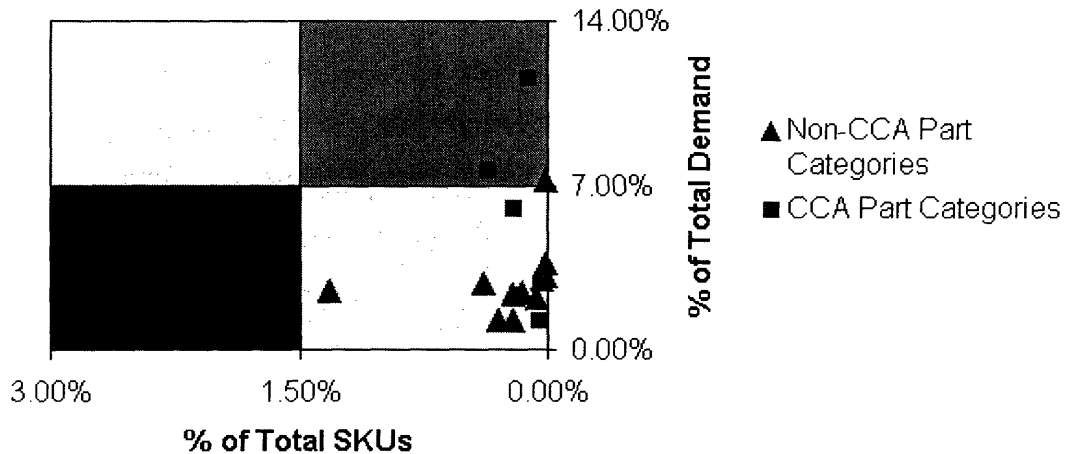


Figure 17: CCAs emerged as the part category representing the most demand dollars and the smallest SKU count

Circuit card assemblies (CCAs) was the part category that noticeably emerged from the pack as a likely SMI candidate. The graph above plots the percentage of total SKU count v. the percentage of total future demand dollars for the 20 part categories that represented the most material demand dollars at Largo.⁴¹ It illustrates how, on average, the various CCA categories represented more demand dollars per unit percentage of SKUs than all other parts in the factory.

A representative CCA is shown below.⁴² Some of the most expensive parts in the factory, CCAs held a total forward demand of \$65M, or approximately 27% of Largo's \$236M forward demand for the entire factory.⁴³ That percentage was higher than any other part category in the plant. Amazingly, those \$65M worth of CCAs only accounted for 0.76% of the total SKU count for the site demand. A great SMI candidate, the CCA

⁴¹ Raytheon NCS Largo system data provided by Chett Gear, Supply Chain Planning Manager, July 2005.

⁴² <http://images.google.com>

⁴³ Raytheon NCS Largo system data provided by Chett Gear, Supply Chain Planning Manager, July 2005.

category showed characteristics identical to what we sought: large demand dollars for an extremely small overall part count.

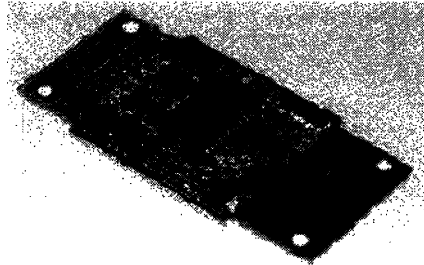


Figure 18: CCAs are expensive parts that represent a significant portion of Largo's demand dollars

Once the team bought into CCAs as our initial SMI piecepart, the next task was to evaluate potential SMI supplier partners. Largo currently has over 25 internal and external CCA suppliers, so there were plenty of options from which to choose. There was not significant variation among the group in terms of CCA volume; the key criteria used to differentiate high potential candidates would therefore be cultural and geographic. One supplier, whom we will call Acme, identified itself as an excellent partner by immediately expressing a willingness to participate. Selfishly, they were motivated to form a long-term partnership with us in order to gain a competitive advantage against other CCA suppliers and thus be better positioned in the future to vie for a larger share of Raytheon's business. For our part, the fact that Acme had two major manufacturing facilities located nearby in Florida was a key selling point. The shipping lead time from their factory to ours was less than one day. Such a short turnaround would prove to be an important asset in the coming months as we move towards more frequent SMI deliveries with shorter interstitial wait periods. Perhaps more significant was the cultural fit. Acme had good performance history with Raytheon, and had a few ex-employees who now worked at Largo. The supplier was immediately willing to share proprietary information with us, and Acme demonstrated commitment to the partnership by involving its leadership team from the beginning. The marriage of Raytheon and Acme was feasible, and we initiated the formation of the new partnership.

tool to respond to situations in real time.”⁴⁵ Clearly the dependence on precise real-time information is paramount to the health of the SOI partnership.

A healthy SOI case in point is the relationship between Hewlett Packard (HP) and SPC International, one of its key suppliers.⁴⁶ In 2001 HP enlisted SPC to perform a comprehensive repair service in order to manage the product returns and warranty requirements. SPC is tasked with handling a variety of HP products including desktops, notebooks, tablet PCs, printers, projectors, and servers. Per the SOI agreement, SPC directly receives the returns at its facility and detrases them. After detricing each unit is either deemed repairable or irreparable. The irreparable units under warranty are written off by HP and replaced by the manufacturer. The repairable units, however, are immediately put under ownership of SPC and promptly reworked. SPC retains ownership of the inventory until it has completed the rework and is ready to ship the repaired unit back to the customer. At the moment the product is shipped, HP’s system buys back the unit from SPC. Throughout the process it is the responsibility of SPC to control the stock levels and ensure there is sufficient stock to supply HP’s demand forecast. In order to plan inventory levels SPC takes into account a variety of factors such as forecasts, stock levels, historical information, and seasonality, among others. All of this real-time information is continuously exchanged between the companies, and trust has been established through the formation of a long-term contract. The crux of the partnership lies in SPC’s cycle time performance and HP’s ability to accurately forecast demand. If SPC were unable to service products quickly and efficiently, HP’s reputation would suffer, and SPC’s revenues would plummet as its assets would be totally consumed in WIP material. If HP could not accurately forecast its demand, SPC could miss revenue targets or be unable to service a demand that is too high. Any of these scenarios would essentially explode the relationship between the companies. HP and SPC have been able to maintain a healthy coexistence by synchronizing their data and

⁴⁵ Andel, Tom, “Vendor, Serve Thyself”, *Material Handling Management*, December 2003, Vol. 58, Iss. 13, pg. 44.

⁴⁶ Lambert, Polly, “HP Case Study: A Streamlined Vendor-Owned Inventory Management Solution”, Captivate Marketing for SPC International, SPC House, Hitchin, Hertfordshire, SG4 0GG.

process flows, facilitating the smooth flux of product and information between the two partners.

4.3 Forming the Partnership: Creating a SOI Win/Win for Raytheon and Acme

How then do we form a partnership with Acme to incentivize them with a carrot while ensuring that they do not get the stick? Lessons from the literature in conjunction with successful real-world cases show that we must protect the financial health of the counterparties while creating a sustainable partnership that is mutually beneficial. In structuring an SOI agreement with Acme, we needed to consider that they would be shipping us CCAs, retaining ownership of them throughout our manufacturing process, and then receiving payment when Raytheon completed final inspection of the finished product. A portion of Acme's cash would therefore be tied up in WIP on our factory floor; we had to assure the supplier that we could process the WIP efficiently so that they would receive a regular, dependable revenue stream. Overall there would be three key issues to address to ensure a healthy partnership between Raytheon and Acme:

- Ensure short Raytheon manufacturing cycle times
- Generate accurate material demand forecasts
- Establish a long-term relationship

The first issue would assure Acme that it could expect dependable cash payments and avoid having too much cash tied up in CCA assets on our factory floor. The second point was important to guarantee that we would require a steady stream of Acme business and not starve them of revenue or increase their inventory. Once we could commit to protecting Acme's financial health, the third issue demonstrates our desire to bond with Acme over the coming years to profit from synergies arising out of our synchronized businesses. Our intention was to sufficiently lean the process at Raytheon as well as contribute resources to Acme to streamline its manufacturing flow as well. Working all of these actions in concert would enable Acme to get the proverbial "carrot" and avoid feeling the brunt of the "stick".

4.4 Thinking Ahead: Breaking Stovepipes and Ingrained Culture with Templated Problem Solving

Upon completion of the reorganization described in the Introduction chapter, the site's culture was in flux. Parochial stovepipes were being broken down as more cross-functional accountability permeated the factory. In the past best-practice sharing across areas was not as common as developing specific solutions applicable only to one area. In the future state R6s sought to promulgate standardization of business processes across the factory to facilitate commonality and synergistic relationship forming within the plant. In the context of our SOI process, I heard talk around the plant that the project would be too specific and insular to be able to be duplicated elsewhere in the factory. The pessimism of the old culture was creating resistance to the acceptance of the fact that new, more efficient practices were going to sweep through the factory as Largo moved towards its future state of lean manufacturing. To counter the naysayers our team had to make sure that we were developing a templated process as we completed our SOI project. By creating a boilerplate framework that would facilitate propagation of the new scheme into other business areas, we would be setting up Largo for future success and easing implementation of our idea in other areas in the months to come.

In discussions with the site executive, he expressed his excitement with our project of implementing the SOI process in one product line to reduce inventory and cost. Insofar as he wanted to see project results that could be translated into other areas of the plant at a later date, our team thought of developing tools that would be versatile enough to be used in various areas of the factory.⁴⁷ Future Six Sigma efforts would attempt to continue the gains from our project in other product lines. To the extent that the process would be repeated, the problem solving methodology required for successful implementation would be nearly identical. Inasmuch as we needed a routinized process, our team endeavored to design standard tools that could quickly address the common implementation issues of inventory bin sizing and cost v. benefit determination. Every SOI or SMI process would require creating novel inventory requirements based on identical calculations.

⁴⁷ Conversation with Luis Izquierdo, Site Executive, and Jay Walsh, R6S Senior Manager, 5 August 2005.

For instance if we were implementing a two-bin kanban in multiple areas of the factory we would follow an identical process of calculations to determine the appropriate bin sizes in order to minimize carried inventory. Facilitating success by making those calculations easier and faster would be incredibly useful. An additional concern that would exist in every implementation is to address the feasibility of the project by looking at its cost v. benefit. Without buy-in from all stakeholders nothing will be achieved, and so it is imperative to show the relevant participants the clear, palpable benefits of the project to demonstrate the financial business case argument. Two standardized tools, one showing proper inventory sizing and another illustrating project cost v. benefit, would therefore enable the R6s group to use the same approach to achieve gains across the factory.

Using a global approach with templated tools, as opposed to parochially developing unique tools for each area, would represent a clear manifestation of the new Largo culture: one that breaks traditional boundaries and facilitates free knowledge sharing across organizational functions. As stewards of the new approach, our R6s team was tasked with being the site's cultural bellwether. Creation of tools therefore had to include much foresight to anticipate the challenges to implementation that lay ahead. Surmounting these future obstacles by mitigating them ahead of time in the process' initial design would enable the creation of templated tools that would have staying power within the organization.

5 Characterize

This chapter begins by introducing the product line involved in the SMI project and presents the transponder product in addition to its production process. After briefly touching upon current inventory replenishment rules and explaining a standard two-bin pull system, a detailed look at an automated bin-size calculator as well as the inputs of a SMI cost v. benefit financial model are presented. Next, steps towards finalizing a supplier partnership contract with the site's strategic vision in mind are outlined. A

literature review of analytic techniques that uncover the true mutual benefit of a SMI partnership finishes the chapter.

5.1 Choosing the Candidate Product Line and Understanding the Process Flow

During the Prioritize stage of the R6s wheel of change analysis was done to determine the best candidate for the project's SOI piece part and supplier partner. After concluding that Acme CCAs were the optimal choice, our team needed to choose a product line as our starting point. The APX-100 transponder line made an excellent candidate because Acme supplied 100% of the CCAs used in the product and the line's management was open to trying to new process. Having most of the stakeholders bought-in from the beginning meant that we had to spend less time convincing people of the SOI process' effectiveness.

5.2 The APX-100: Identification Friend or Foe Transponder

The APX-100 transponder has been produced by Raytheon since 1978 and is the smallest, lightest Mark XII Diversity Transponder in the world.⁴⁸ Used for a multitude of military applications on the ground, at sea, and in the air, the APX-100 distinguishes foreign platforms as friendly, enemy, or neutral. Enabling military forces to tell who their allies are, the system has been fielded on over 50 different platforms and more than 15,000 total sets have fielded since the product's inception.

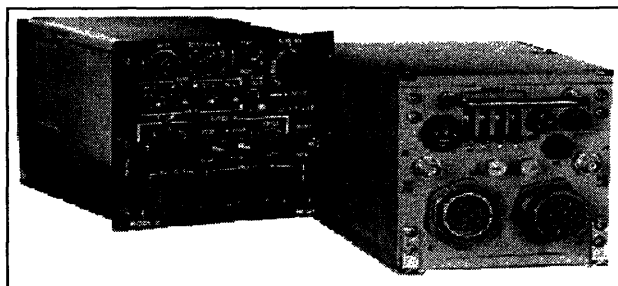


Figure 19: The APX-100 transponder has identified foreign platforms as friendly, enemy, or neutral for over 25 years

⁴⁸ Raytheon APX-100 product description, http://www.raytheon.com/products/apx100_v/, accessed 24 October 2005.

The final product shown above weighs 10.0 pounds and has dimensions of 5.4 x 5.4 x 8.4 inches. It is featured in a variety of military vehicles including F-18 jets, C-5 transports, MiG fighters, and several unmanned aerial vehicles like the Predator and Global Hawk.

5.3 The APX Manufacturing Process

In order to understand the manufacturing process and properly characterize the current state of the system, our team assembled a cross-functional group to discuss and map the APX process flow. Both floor personnel and salaried support staff took part in the meeting to accurately depict the value stream, and we utilized the lean technique of mapping the process on the wall using individual sticky notes for each step of the flow. The output of the discussion is shown below; at top is the actual result that the group generated during the meeting, at bottom is a simplified version to highlight the CCA flow and main steps of the process.

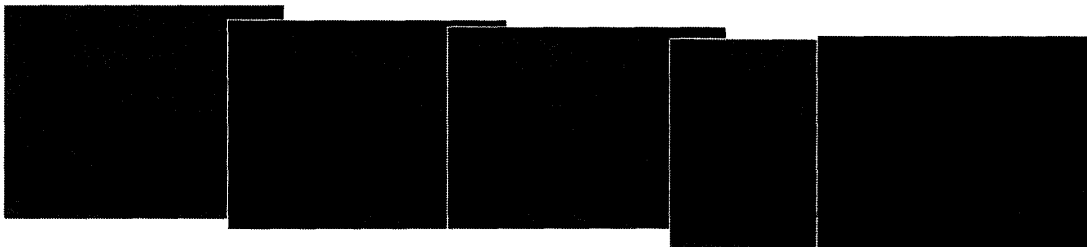


Figure 20: The R6s SOI project team created the process flow map for APX

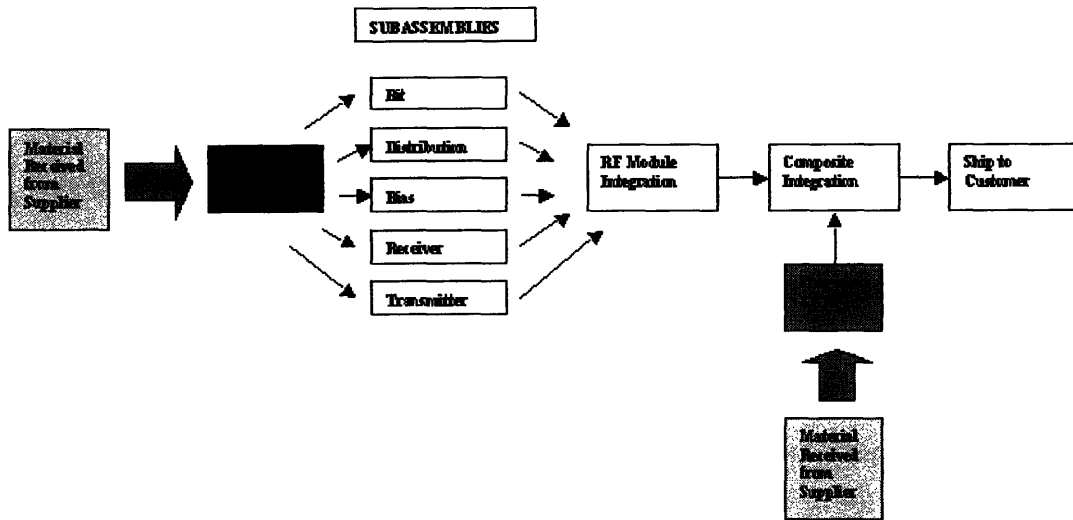


Figure 21: A simplified version of the process flow map for discussion purposes

The simplified process flow is as follows. Common CCAs, or the cards that go into every transponder produced, are delivered to the five subassembly workstations: the transmitter, receiver, bias, distribution, and bit subassemblies. The subassemblies are built in parallel, and after being inspected and tested travel to the radio frequency (RF) module integration. At integration the five subassemblies are pieced together to make the RF module, and it is then inspected and tested. When the RF module is complete, a specific combination of plug-in CCAs, the cards that determine the transponder's type, are inserted into the unit. There are many configurations of APX transponders, all taking common CCAs; however each individual configuration requires a unique combination of plug-in CCAs. When the final product, the composite APX-100 transponder, is complete the unit is shipped to the customer.

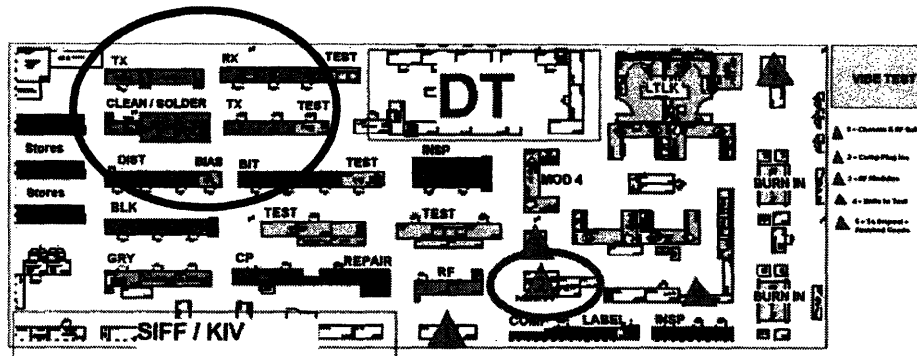


Figure 22: Common APX subassembly CCAs are replenished at the beginning of the process (large circle) and plug-in CCAs are replenished at the end of the line (small circle)

There are two main areas where CCAs are replenished on the floor, shown by the circled regions in the line layout below. Within the larger circle on the upper left of Figure 22 are the subassembly areas where common CCAs are stocked. The smaller circle to the lower right of Figure 22 depicts the plug-in CCA stock where the specific cards are inserted into the completed RF modules. There are 20 common CCAs and 22 plug-in CCAs. That would require 42 total bin-sizing calculations to determine the minimum requisite replenishment water levels to guarantee that the line would have no stock outs.

5.4 Current Replenishment Run Rules

Acme delivered boxes of CCAs to the stores located at the end of the product line, shown at the extreme left of the floor layout above. At six o'clock every morning the material handler checked each station that required common or plug-in CCAs to determine whether it needed to be restocked. There were no run rules for the replenishment; it was the material handler's prerogative to choose whether there were enough CCAs for the day's build requirement. If a bin looked low he would add CCAs as he saw fit. Without maintaining a constant count of material, he could add however many cards were available in stores. Oftentimes there would be too many CCAs at a workstation, while at other times a bin might be left empty. The surplus cards that would not fit at the workstation were kept in large boxes in stores, illustrated in the picture below.



Figure 23: Many weeks' worth of CCA inventory exists in stores for the APX process

The CCAs at the workstation were kept in metal racks that were connected by a hanger, and example of which is shown in the picture below. Each hanger contained two racks, and each rack contained one or more types of CCAs. The example below depicts a single hanger holding two CCA racks, each of which is holding one type of CCA. Since the racks were connected by a hanger, only an entire hanger could be removed from the workstation. This meant that each bin could not be replaced individually; rather one would have to replenish multiple racks of cards at once. The current rack infrastructure made it impossible to use as an efficient kanban system because the metal racks were not individually interchangeable.

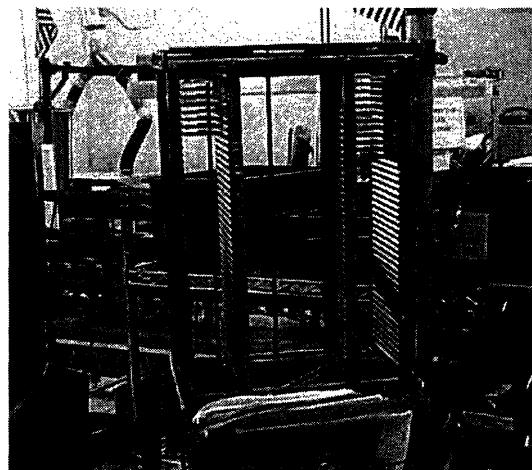


Figure 24: Metal racks holding CCAs inhibit individual bin replenishment and encourage overstocking

Clearly there was no pull or replenishment signal involved in the replenishment process. MRP pushed CCA orders into the factory as the cards accumulated in boxes within the stores area. In addition the material handler would push material every morning into the workstation bins when he felt that they should have more material. Nothing about the system relied on the customer takt or need-based replenishment. Inasmuch as material was continually pushed to the point where the CCA inventory on the floor continually grew, there were over two months' worth of CCAs in stores when our project began. The total CCA on-hand inventory was initially valued at more than \$465 thousand.⁴⁹

5.5 The Two Bin Pull System

The kanban replenishment has been a staple of manufacturing firms for many years since it was invented as part of the Toyota Production System. The prescience of Shigeo Shingo, a former industrial engineer at Toyota, helped create the two-bin philosophy that is both simple and effective. The system's tremendous utility in decreasing inventory has fueled its spread into other industries. Today various companies like Intel, Honeywell, Alcoa, and Boeing have implemented some form of the kanban pull system in their manufacturing processes to visually manage inventory levels.^{50 51 52 53} To the extent that the pull system is widespread and well understood, only a very brief introduction to the concept is provided in this thesis.

⁴⁹ Email conversation with Deborah Mitchell, Material Program Manager, 26 October 2005.

⁵⁰ Connally, Jason, "Targeting Lean Improvement Efforts & Introducing Pull Methodologies in a Semiconductor Fab", Intel Corporation, Massachusetts Institute of Technology, Leaders for Manufacturing thesis, June 2005.

⁵¹ Chesborough, Amber, "Inventory Reduction for Commodity Aerospace Parts", Honeywell International Incorporated, Massachusetts Institute of Technology, Leaders for Manufacturing thesis, June 2004.

⁵² Kimber, Michael, "Definition And Implementation Of A Visual Inventory Management System", Aluminum Company of America, Massachusetts Institute of Technology, Leaders for Manufacturing thesis, June 1999.

⁵³ Micheau, Victoria A, "How Boeing and Alcoa Implemented a Successful Vendor Managed Inventory Program", *The Journal of Business Forecasting*, Spring 2005, 24, 1.

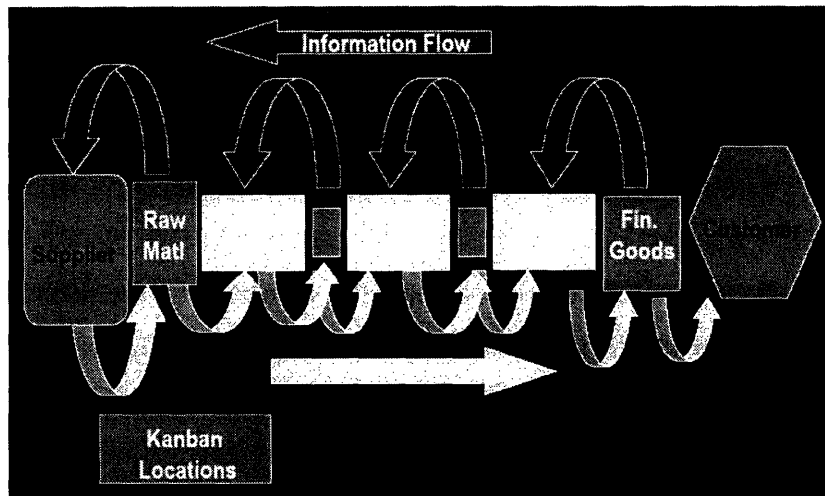


Figure 25: The two-bin kanban system passively controls inventory and information flow to minimize waste

The above diagram succinctly illustrates the key concepts of the pull system.⁵⁴ The arrows at the top of the picture show how information flows from the consumer up the value stream towards the supplier. In production this information would include the need for replenishment of material. When a channel upstream receives the information, the required parts flow downstream as indicated by the arrows at the bottom of the picture. The signals that transmit the information are called kanbans and are represented by the interstitial boxes between process steps. The two-bin system uses empty bins as kanbans in the following manner. Each workstation is stocked with two bins of material. When one bin has been exhausted by the operator, it is left empty and signals the channel upstream for more material. While the upstream channel is taking time to replenish the first bin, the operator uses his second bin of material. Theoretically, the replenished first bin should arrive back at the station before the operator has completely exhausted the second bin. This cyclical process repeats indefinitely as the inventory is managed visually. Lowering the bin size, or replenishment water level, keeps material inventory at a minimum while guaranteeing an absence of stock-outs.

⁵⁴ Stauffer, Larry, et al, "An Introduction to Lean", Idaho Manufacturing Conference presentation, 13 October 2005.

A fundamental difference between this pull system and the traditional push system employed at Raytheon is the flow of information. Revisiting the push flow diagram discussed in the Visualize chapter of this thesis, one notes that customer orders are first logged into the MRP system. Based on the MRP material lead times, the system then pushes material into the factory based on scheduled delivery dates. MRP is therefore telling the production floor when it should need material. If there were no contingencies in production, for example bad first-pass yields or excessive operator absenteeism, then manufacturing would likely perform to the MRP schedule and the system would work well. The real world of manufacturing does not work consistently to a rigid MRP schedule for innumerable reasons, and the factory thus requires a replenishment system that flexes with the varying demands of production. Since these production requirements fluctuate it makes sense to have the communication stem from those parties closest to the source of variation, the consumer. In essence this is just what a pull system does; it allows information to percolate upstream just in time for replenishment material to flow downstream.

Not to be understated are the drastic cultural differences between the push and pull systems. In the push environment people are often accustomed to large inventory buffers and have a visual comfort zone in knowing there is an available surplus of material to mitigate any potential contingencies in production. There does not have to be an enhanced level of trust with the next upstream channel for on-time material delivery because the buffers are adequate cushion for bad performance. In contrast the pull environment takes away excessive stores of inventory and requires deft, timely replenishment performance from all channels in the value stream. Minimizing inventory levels and relying on fast turnover between channels commands a high level of trust among the stakeholders. It is this trust that must permeate an organization's culture; the sentiment can only be built over time and is much easier to squander than to maintain.

5.6 Automating Daily Build Rate & Bin Size Calculations: The Bin-o-matic

In the Visualize chapter we illustrated and described the current method of calculating daily takt. Relying on customer shipment dates, the manufacturing personnel would use

a back-of-the-envelope calculation to “back into” a daily build rate. Based on this build rate, material replenishment requirements were generated and given to Acme. Anecdotal delivery and manufacturing lead times were implied in the calculations, leading to the inclusion of various unnecessary buffers.

The new SOI partnership required accurate material forecasts. Since we were asking Acme to allow us to tie up a portion of its cash in the CCAs on our manufacturing floor, we had to give them continually updated, accurate demand information that would make the data exchange interface completely transparent between us. In lieu of buffers and anecdotal calculations, we needed data-driven interchanges that pushed the operational efficiency of both them and us. The excess CCA inventory for the APX line would not improve by simply implementing a two-bin kanban system alone. If buffers in demand calculations persisted, excessive CCA inventory could remain.

The cultural change implied in such electronic data interchange (EDI) was remarkable. Historically at Raytheon the only communication between the company and its suppliers came in the form of a purchase order (PO).⁵⁵ The PO was just a material request that provided no insight into future demand; it was a discrete one-time-only contract to buy a specified quantity of parts. Not only was the idea of exchanging sensitive information including demand and manufacturing process data novel, but it also necessitated an incredible amount of trust between the counterparties that was heretofore nonexistent. The importance of the trust underpinning the SOI agreement was touched upon briefly in the Visualize chapter and more thoroughly discussed in the Commit chapter.

In order to generate accurate takt rates and material replenishment quantities, I created an Excel tool called the Bin-o-matic. The goal for the tool was to provide a user-friendly template for utilization across the factory that could take material demand data directly from MRP and automatically calculate takt rates and material replenishment forecasts. Using minimal inputs from the user, the tool automates inventory sizing allowing a manufacturing process to accurately know the minimum amount of material it requires to

⁵⁵ Conversation with Dan Long, Purchasing Manager, 2 November 2005.

meet customer, and therefore production, demand. There advantages of the tool are threefold.

First, the tool makes it easy for production personnel to properly size kanban replenishment bins. On at least one occasion when kanban bins were put in place within the factory, the bins were sized according to the manufacturing line's maximum capacity. For example if a particular line could assemble a maximum of eight finished products per day, the kanban size would be eight. This approach did not take into account future demand rates; the bins were sized exclusive of customer takt. Inevitably these kanban bins would carry excess inventory. The only scenario when the bins would not have surplus material would be if the line were running at 100% of capacity - a rare situation indeed. In contrast the Bin-o-matic uses consumer demand data to determine replenishment levels. With this method the inventory levels ebb and flow according to customer pull. Allowing kanbans to only carry sufficient, not excess, inventory ensures that the production line is consistently fed only what it needs and will not face a stock-out situation.

Second, the Bin-o-matic forecasts the material replenishment schedule used by operations managers and suppliers. With a pull system in place, suppliers would no longer deliver material according to a set schedule. Instead they would wait until the kanban signal, an empty bin, prompted them for more material. Such a kanban system works wonderfully for the production line, but it does have undesirable side effects. On the one hand the lack of scheduled deliveries may make it difficult for a supplier to predict his revenue. Not being able to forecast sales and to execute to that sales plan would be a death knell for any business. On the other hand though, the Bin-o-matic provides an accurate estimate of future deliveries that suppliers can use to predict revenues. Because the tool bases the delivery schedule on actual demand data, and not anecdotal evidence, it generates a more precise outlook that suppliers can take to the bank.

Third, production personnel can use the tool to automatically calculate their daily build rate. This thesis has already discussed how using anecdotal production takt creates waste

in various forms. Eliminating that waste means that a customer-driven takt must be established as the drumbeat of production flow. To that end, the Bin-o-matic uses Webplan demand data to automatically calculate the true customer takt, taking a lot of manual work out of the current process. The tool generates and displays the accurate leveled rate of production that Largo must maintain to meet its customers' demands.

Part Number	Past Due	Current Week	Week +1	Week +2	Week +3	Week +4	Week +5	Week +6	Week +7	Week +8	Week +9	Week +10	Week +11
4043923-0501	48	30	41	0	42	60	31	30	24	10	0	41	64
4044151-0501	3	1	0	2	0	0	0	0	0	0	0	0	0
4044162-0501	16	1	0	12	15	0	0	21	15	15	0	0	17
4044336-0501	16	1	2	12	15	0	1	21	15	15	0	0	17
4044351-0501	16	1	0	12	15	0	0	21	15	15	0	0	17
4044503-0501	8	0	10	0	0	0	0	15	0	15	0	11	6
4047430-0501	16	1	1	12	15	0	1	21	15	15	0	1	18
4047434-0501	0	20	0	0	26	0	0	0	0	0	0	20	20
4047434-0502	18	5	1	12	15	0	1	21	21	15	0	0	20
4054444-0501	0	0	0	0	0	0	0	0	0	0	0	0	1
4054444-0502	0	0	2	0	0	0	1	0	0	0	0	0	0
4060586-0502	24	15	20	0	21	40	15	15	12	5	0	20	32
4060587-0501	24	15	20	0	21	40	15	15	12	5	0	20	32
4068733-0501	2	1	0	1	0	0	0	2	0	0	0	0	2
4068736-0501	2	1	0	1	0	0	0	2	0	0	0	0	2
4068742-0501	2	1	0	1	0	0	0	2	0	0	0	0	2
4068670-0501	6	0	0	0	3	0	0	0	0	0	0	0	3
068875-0501U	4	0	0	4	2	0	0	3	0	0	0	0	3
4068881-0501	0	0	0	3	0	0	0	0	0	0	0	0	3
4068945-0501	4	0	0	4	0	0	0	3	0	0	0	0	3
4069027-0504	2	0	2	0	0	0	2	0	6	0	0	2	1
4069030-0504	2	4	1	0	0	0	1	0	6	0	0	1	1
4070771-0502	0	0	0	0	15	0	0	21	0	15	0	0	0
4070826-0501	6	0	6	5	0	6	6	4	0	0	0	0	9
4071065-0501	6	0	0	0	0	0	0	6	0	2	0	0	0
4071069-0502	12	0	3	10	0	12	3	8	0	0	0	0	9
071075-0500U	0	0	1	0	0	0	1	0	0	0	0	1	0
071094-0502U	58	2	2	23	57	6	17	15	5	42	0	0	10
071096-0501U	1	2	0	1	0	6	6	3	0	0	0	0	6
071096-0502U	57	0	0	22	55	0	16	12	5	42	0	0	10

Figure 26: The Bin-o-matic data input screen displays part number (column A) and weekly demands (columns B through N)

Microsoft Excel - Bin-o-matic rev4.25.D01 with fresh WebPlan data.xls

File Edit View Format Tools Data Window Help

Weekly Demand for:

These calculations assume a 2-bin system (1 daily bin at workstation, 1 daily bin in store)

Part Number:	Initialization	24-Oct-2005	Week +1	Week +2	Week +3	Week +4	Week +5	Week +6	Week +7	Week +8	Week +9	Week +10	Week +11	Week +12
4043923-0501	12	78	41	0	42	80	31	30	24	10	0	41	64	50
4044151-0501	1	4	0	2	0	0	0	0	0	0	0	0	0	0
4044162-0501	1	17	0	12	15	0	0	21	15	15	0	0	17	10
4044336-0501	4	17	2	12	15	0	1	21	15	15	0	0	17	10
4044351-0501	4	17	0	12	15	0	0	21	15	15	0	0	17	10
4044503-0501	4	8	10	0	0	0	0	15	0	15	0	11	5	0
4047430-0501	0	17	1	12	15	0	1	21	15	15	0	1	18	10
4047434-0501	0	20	0	0	26	0	0	0	0	0	0	20	20	0
4047434-0502	0	23	1	12	15	0	1	21	21	15	0	0	20	10
4054444-0501	0	0	0	0	0	0	0	0	0	0	0	0	1	0
4054444-0502	0	0	2	0	0	0	1	0	0	0	0	0	0	0
4054444-0503	0	0	0	0	0	0	0	0	10	1	0	0	15	7

Bin-o-matic / BMS WebPlan Data.xls / ENTER PART NUMBER HERE

Ready

Figure 27: The Bin-o-matic tool's user interface downloads and displays demand data and prompts user input for kanban bin size

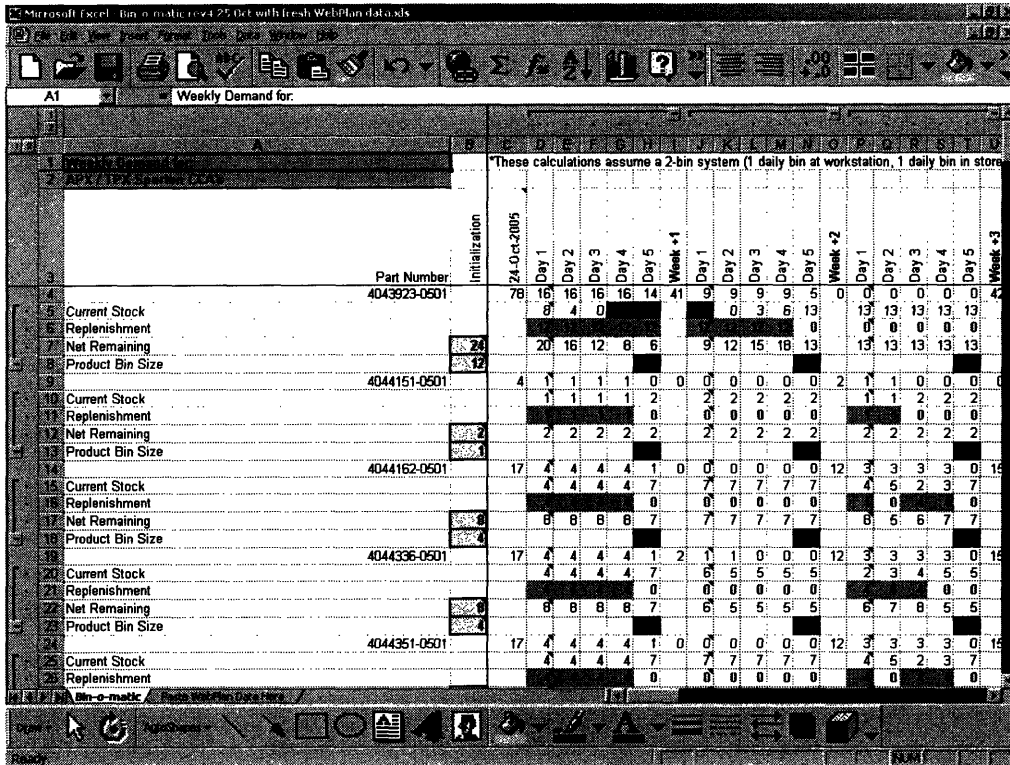


Figure 28: The tool levels production rates and uses bin size user input to calculate supplier replenishment schedules and remaining stock quantities

The user interface is illustrated by the three screenshots above. The top screen shows the underlying Webplan customer demand data. Exported to the Excel workbook, the data lists required part numbers in the extreme left column with their accompanying demand numbers tranced in weekly buckets. In this example the part numbers given are the actual CCAs being used in the APX product line. The total time period of 13 weeks was chosen for the tool since it represents one fiscal quarter.

The middle screen shows the collapsed interface of the Bin-O-Matic calculation tool. In column A the CCA part numbers are listed and the weekly demand buckets, represented in columns C, I, O, etc, are automatically populated directly from the imported Webplan data. Note that this screen is not telling us any new information, it is simply another representation of the Webplan weekly demand.

The third and final screen shows the expanded tool interface. Vertical expansion of the worksheet reveals rows showing *current stock*, *replenishment amount*, *net remaining inventory*, and the part's kanban bin size. Horizontal expansion of the worksheet uncovers intraweekly build rates, starting with the first week beginning on 24 October 2005 in this example. Each week is broken into its five constituent days, and the weekly build requirement from Webplan is automatically divided among those days to generate a leveled daily build rate. Column B contains the yellow user input cells. In the rows titled *Product Bin Size* the user enters a bin size to see whether it is sufficient to meet the daily demand requirements. For an example let us start in cell B8, the user input cell for CCA #4043923-0501. The initial bin size entered is 12, and let us assume that we are starting a new two-bin system. We begin therefore with two bins of 12, making 24 total CCAs in net remaining inventory, shown in cell B7. The sheet indicates in cell C4 that our first week's demand is 78. Level-loaded within the tool, the first day's build requirement is calculated to be 16 shown in cell D4. Using 16 CCAs of our total 24 means that we would have eight CCAs left after the first day's builds. These eight CCAs are shown in cell D5, the *Current Stock*. Having eight cards left in current stock on the first day means that we had burned through one of our 12-card kanban bins, gone below the water level, and thus would require replenishment at the end of the day. This bin replenishment is represented in green *Replenishment* cell D6. After the one bin replenishment the *Net Remaining* cell D7 indicates that there would be 20 CCAs left at day's end.

Continuing the process in the same manner, one can follow the calculations through the weeks and see not only when replenishment is needed, but also whether there is enough net remaining material to meet the following day's build requirement. Continuing with our example above we notice in red cell G5 that there is not enough material to meet the takt rate in Day 4 of the first week. That denotes that one would have to increase the bin size in cell B8 to accommodate the production needs. The reader may notice that the subsequent part numbers below our example on the screen have enough material to meet demand as no cells in the *Current Stock* rows are colored red with negative values.

Through the method above the Bin-o-matic makes quick and accurate calculations that have a powerful effect on inventory and production. The tool can have drastic implications on inventory and supplier planning by determining the proper bin size, replenishment schedule, and build rate for any part number.

5.7 Illustrating Cost v. Benefit: The Elements of the SMI Financial Model

As previously discussed the SMI cost v. benefit analysis, or total cost of ownership (TCO) model, is a key component of SMI's success. By attempting to capture all manufacturing activities and items affected by the new replenishment arrangement, the TCO model is able to lucidly illustrate the tangible advantages of the concept. Its contribution to effective stakeholder buy-in cannot be overstated, as many people are more easily convinced when they see hard data conveying the palpable benefits of an idea.

The development of the model was a large endeavor involving team members from four of Raytheon's six businesses. We sought to collectively develop a plug-and-play SMI TCO model that could be utilized across all Raytheon business units. The variety of vantage points within our cross-functional team was a boon to the creation of a flexible model that would have staying power within the organization. However the disparity of tribal knowledge among the team meant that discussions often had to progress extremely slowly as concepts were translated from one group's vernacular into a language that the larger team could understand.

Representing the manufacturing areas affected by SMI, the elements of the TCO model were separated by category into the following list. A brief description of each element is included below.

- Sourcing
- Receiving and inspection
- Warehousing
- Production floor

- Accounts payable
- Engineering
- Quality
- Material related costs
- Carrying cost
- Non-recurring conversion, equipment, and miscellaneous costs

First, sourcing activities like PO placement, maintenance, follow up, and closure should be affected by SMI. Our project aimed to automate the PO process by allowing the supplier to generate most of the POs for us over the course of the fiscal year.

Second, receiving and inspection should feature reduced activity in the SMI environment. Less source and sample inspection should be needed for a trusted supplier partner, and much detrashing and manual tracking can be eliminated by using reusable kanban totes for incoming parts and integrating suppliers into the MRP system via regular electronic data interchange (EDI).

Third, warehousing activity is tremendously affected by SMI as most of the inventory management tasks are outsourced to the supplier. Inventory audits, picking, labeling, repackaging, and shelf life management would be minimized for the manufacturer as the supplier partner takes responsibility for many of these actions.

Fourth, production floor activities such as stock outs and defective material identification could change significantly. Coordination across functions to expedite material from a supplier in the event of a stock out would be different, and generating reports and inspections for defective material might be handled in new ways if the supplier partner is tasked with determining fault for parts identified as outside specification tolerance.

Fifth, allowing a supplier to independently generate intermittent POs when material is required by the manufacturer affects activities in the accounts payable department. Check generation, payment dispute reconciliation, invoice reviews, and ledger postings

would be altered in the SMI environment. Many of these tasks might be more easily automated through electronic data exchange while others, for example payment reconciliation, may be more labor intensive in the new arrangement.

Sixth, SMI could affect engineering and quality by requiring, perhaps, new work cell design to facilitate POU delivery and changing the process of defective material disposition. When the supplier is handling the bulk of the floor's intrafactory material, assigning fault for and disposition of defective material is more difficult. The quality department's supplier rating system may also need a change made to its maintenance requirements. Because the SMI supplier partner is tasked with more activities, the metrics behind the ratings would need to be updated to effectively measure the performance of the new arrangement.

Seventh, material related costs, for example paying material expedite premiums, could also be affected by SMI if expediting activity is changed in some manner.

Eighth, non-recurring costs of SMI setup could arise within the information technology and facilities departments. Supplier contract modifications must be made to allow traditional hard copy contracts to exist in an automated electronic form in the online system. IT may also be tasked with establishing virtual discrete bin locations that correlate to supplier delivery zones on the floor. In addition, facilities may need to change the physical layout of the work cells to accommodate SMI activity, resulting in a non-recurring expense.

Finally, carrying costs may change with SMI pending changes in average on-hand inventory. Any changes in scrapped, damaged, or obsolete material resulting from SMI implementation might have an effect on overall site inventory.

5.8 Finalizing the Acme SOI Contract and Ensuring Forward Demand, Cycle Times, and Engagement Longevity

Three key ingredients to a healthy SOI relationship were identified in the Prioritize chapter: maintenance of efficient manufacturing cycle times, ensuring forward demand requirements, and commitment to a long-term relationship.

The first facet of the SOI agreement that Raytheon needed to investigate was the cycle time on the APX product line. The contract was structured so that Acme would own the CCAs from the time of delivery, through the manufacturing process, and up until the transponder product passed final inspection. At the moment final inspection was completed, Raytheon would take ownership of the CCA and remit payment to Acme. Simply stated Acme would own the CCAs all the way through our factory until we were finished manufacturing the product. Because Acme's CCAs remained on their ledger until our factory's final inspection, Acme would have a significant portion of its cash flow tied up on our floor in the form of CCAs. The supplier therefore needed a guarantee that we would efficiently process Acme's CCA inventory so that they could rely on a regular stream of cash payments. Without such a promise the supplier would be exposed to the risk of Raytheon accruing too much CCA inventory in its factory that would leave Acme asset rich and cash poor – a precarious financial position. To mitigate that contingency we included a maximum 35-day payment window for Raytheon within the SOI contract. Transponders that passed final inspection in less than 35 days would generate payment at the time of completion; those that lingered in process after 35 days would have a payment automatically generated on the 35th day, no matter where the transponder was in the manufacturing process. In this manner Raytheon guaranteed Acme would receive payment for its CCAs in a timely and predictable fashion.

The period of 35 days was not chosen at random. On the contrary it was derived to include a significant buffer on top of the actual cycle time of the APX product line. The figure below shows representative cycle times for seven of the APX transponder types; though the actual times have been changed, the trend remains the same.⁵⁶ The cycle

⁵⁶ Cycle time data taken from Raytheon NCS Largo RGS 201 report for closed product routers between 2 March 2005 and 2 September 2005, generated 26 September 2005. Labor time charged data taken from Raytheon NCS Largo RGS 305 report for times charged between 1 January 2005 and 23 September 2005, generated 26 September 2005.

times shown are the average product cycle times from all finished transponders in the six-month period from 2 March to 2 September 2005. The thick horizontal line at the top of the chart demarcates the 35-day contractual stop date.

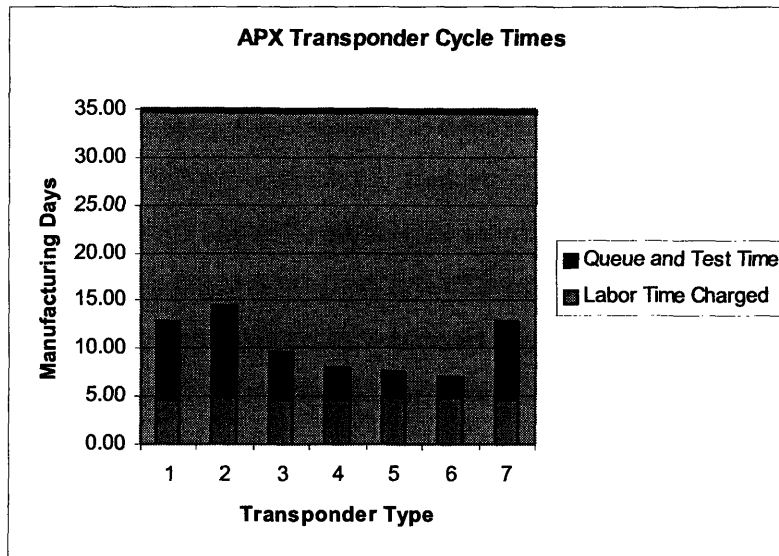


Figure 29: The 35-day contract payment window (shown by thick horizontal line) provides a significant buffer over average APX cycle times

The buffered period of 35 days was chosen to allow for significant variability in the average cycle times. The product line still had work to do to eliminate issues with low first-pass yields and batching that contributed to volatility in the transponder cycle times. In order to have consistent run rules for Acme payments at the beginning of the process' implementation, our group chose the 35-day window to take the cycle time variability into account. If we had not considered the volatility and chosen a payment window of 15 days for example, the success of the SOI process' implementation might be at risk. Since cycle times would often peak above that 15-day period, many SOI payments would be generated while a CCA was still in process. From the outset this would make payment run rules inconsistent and confusing, thus jeopardizing SOI's chances of success. Acme agreed to the time period and understood that, on average, they would be receiving payments from Raytheon in roughly half the total time allowed by the window since the average APX cycle times for various transponders were less than half of the 35-day

allotted window. The underlying stipulation behind the 35-day period required Raytheon to gradually pare down the allotted window over time as the product line cycle times became more efficient and less variable.

A second key ingredient to a healthy SOI relationship is the ability to ensure forward material requirements to the supplier. As a win-win proposition the SOI process is meant to enable both manufacturer and supplier to lean their respective manufacturing operations to match level-loaded material flow to customer demand. That way each party can reduce costs by elimination of herky-jerky production flows and needless stores of surplus inventory. However, in order to level load the supplier must know forward customer takt information – just the sort of demand outlook that has historically been kept close to the vest of Raytheon. In fact one Largo procurement manager noted that approximately 95% of the site’s suppliers never receive forward demand information.⁵⁷ Typically these suppliers, Acme included, only received a monthly purchase order for a one-time quantity requirement. Future requirements were shrouded in secrecy, as the idea of constantly switching suppliers for the lowest cost kept counterparties from sharing sensitive information. The new scheme of demand data transparency, therefore, represented an entirely new approach that entailed a more profound trust and higher level of engagement between Raytheon and the supplier. In agreeing to enter the SOI scheme with Largo, Acme required a firm commitment from Largo to purchase certain quantities of future material. Without such a guarantee Acme would be unable to accurately set quarterly revenue targets and to reduce its safety stock without exposing itself to undue risk of material shortage. To mitigate these concerns we contractually bound ourselves to providing Acme with the following information on a monthly basis.

- **Firm CCA demand** requirements for three months forward
- **Forecasted CCA demand** for the successive nine months thereafter, totaling 12 months of demand data provided to Acme

⁵⁷ Conversation with Dan Long, Purchasing Manager, 2 November 2005.

In this manner Acme would have a rolling 12-month look at Largo's CCA material requirements. As the fourth month rolled from the forecasted window into the firm 90-day demand window, we agreed that any changes in demand quantity for the new month three would be within a tolerance of plus or minus 25%. As the more forward months were rolled closer, they too must adhere to quantity changes within the 25% range. With all changes taken into account the total quantity for any 12-month period also could not fall outside of the 25% tolerance. Keeping Largo's CCA demands within this range would allow Acme to:

- Significantly reduce its safety stock
- Firmly commit to upcoming quarterly revenues
- More accurately forecast annual revenues

An important final piece to a robust SOI engagement is a long-term commitment. In order to generate a foundation of trust and to facilitate information sharing between parties, binding the manufacturer and supplier together for an extended period of time encourages teamwork. Nonetheless, as the pilot Largo SOI project the Acme engagement represented a peculiar circumstance. On the one hand both parties wanted to show commitment to promote successful implementation of SOI and realize its benefits. On the other hand however they want to have a contingency plan releasing them from liability if SOI proves unfeasible. Heretofore unproven at Largo, SOI needed to demonstrate its own worthiness before both Raytheon and Acme were willing to contractually commit themselves for an extended period. An important incentive to abet SOI adherence, the contract thus did not include a dated long-term commitment. Without a contractual incentive the SOI project would have to rely on alternative feedback loops, such as positive team dynamics and quick wins, to keep the process on track for success.

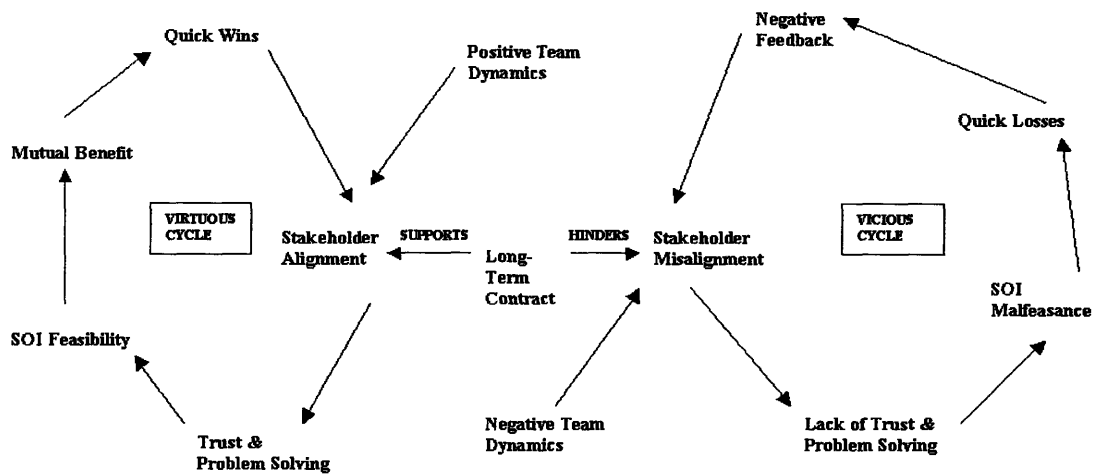


Figure 30: A causal loop analysis of the supplier partnership illustrates alternative methods of keeping the process on a virtuous cycle

The causal loop diagram shown above shows how central the long-term contract is within an SOI relationship.⁵⁸ In practice the contract can be the deciding factor on whether SOI engagement succeeds or fails. Without such a long-term agreement our team had to circumvent that requirement in order to move the project along the virtuous cycle to success. To avoid the vicious cycle we needed stakeholder alignment. One way to achieve alignment without a contract is to ensure functional team dynamics. By choosing SOI team members that can synergistically work together, and by facilitating efficient information flow among the group, we could inject enough functionality to maintain stakeholder alignment. For a synergistic Largo team we chose members who had an optimistic view of SOI and understood its potential benefit for the site as a whole. SOI skeptics at Largo, although kept up to date on the team’s progress, were left off the pilot team for the seminal SOI implementation. We were unable to choose the Acme team members because they were assigned by the supplier. Fortuitously the representatives chosen by Acme worked extremely well with our group. The synergies and personalities among the team felt like a good match from the beginning. Efficient information flow also helped maintain the stakeholder alignment. We set regular weekly face-to-face meetings and kept team members continually updated intraweekly with periodic emails.

⁵⁸ Bonini, Jamie, “Case Study On Designing Performance Measures To Nurture Cultural Change On The Factory Floor”, Massachusetts Institute of Technology, Leaders for Manufacturing thesis, June 1992.

Actions and accountability for each team member were clearly defined and were logically strung together to push the idea of SOI along its journey to successful implementation. Everyone made the initiative a priority and gave the project the attention and time it needed to come to fruition.

5.9 Thinking Ahead: Keeping Future State POU in Mind as SOI Implementation Proceeds

The previous discussion of disparate inventory management methods outlined why POU is the inventory management scheme of choice for myriad world-class manufacturers. Keeping 100% of a factory's inventory in bins at workstations where it is actually consumed is a tremendously powerful way to minimize total inventory. By obviating the abyss that is a central storeroom there is nowhere for material to "hide" in the factory; rather, it is all clearly visible as it is laid out at the workstation. The future state of Raytheon Largo features exclusive use of POU. Using a two-bin system the POU replenishment rules require material delivery directly to the workstation. In contrast the current state at Largo utilizes a central storeroom located away from the workstations that does not utilize a two-bin system.

With the future state in mind our group decided to incorporate the run rules of a two-bin system into our SOI project. We could easily implement SOI without affecting the current replenishment rules on the floor; SOI technically only affects virtual information exchange and point-of-sale. The project would be much more easily implemented if we did not require changes in human behavior from floor personnel. However, if the run rules were changed now to include a two-bin system then POU would be much more quickly and easily rolled out in the factory at a later date. In order to begin blazing the trail for the journey towards POU, and eventual achievement of the future state, our team rolled out the two-bin system for the APX product line.

The bin system we employed was not a true POU scheme because both bins were not stored at the workstation. Instead, one bin was kept in the storeroom while the second was kept at the workstation. Space concerns on the assembly line inhibited both bins

being stored there. To achieve buy-in from the floor managers we could not go directly to daily bins of material after recently having multiple months' worth of inventory in stores. A drastic change like that would have been too radical, and neither Raytheon nor Acme was yet ready to effectively maintain the velocity of run rules that scheme would require. As an intermediate step then we sized weekly bins so that one bin resided at the workstation, while the second sat in stores. The large size of some of the bins, for example one particular weekly container held 48 CCAs, prevented us from collocating the bins at the station. While not a perfect POU system, the two-bin scheme we used did effectively introduce the run rules of bin replenishment so that the floor personnel could become accustomed to its requirements. Also it achieved buy-in from all relevant stakeholders including the front office, floor management, assembly line operators, and material handlers. While we did not follow the path of least resistance, our team found a way to effectively cross the chasm towards the future state. By choosing a method palatable to all parties involved that pushed the state of Largo manufacturing closer to world-class standards, we began to achieve mindset shifts and laid the seeds of cultural change.

5.10 Literature Review: Overcoming Implementation Barriers: Economic Value Added (EVA) Analysis

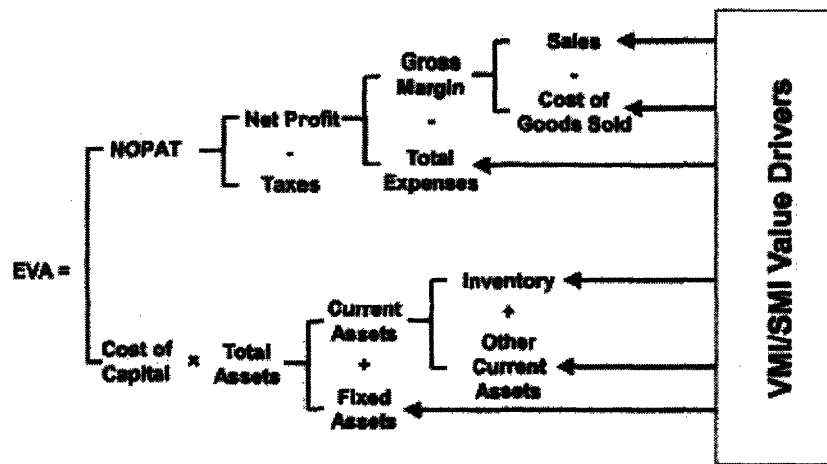
The Commit chapter discussed how different stakeholders within Largo require varied incentives to accept SMI as beneficial to their jobs. To convince people that the new inventory management method is indeed advantageous, one must illustrate palpable benefits. Pohlen and Goldsby propose a method outlining SMI benefits that they call Economic Value Added (EVA).⁵⁹

A technique employing a combined EVA analysis of the supplier-customer relationship may assist managers in overcoming the implementation barriers. The application of EVA enables managers to determine how SMI/VMI will affect value creation within each firm. The

⁵⁹ Pohlen, Terrance, and Goldsby, Thomas, "VMI and SMI Programs: How Economic Value Added Can Help Sell the Change", *International Journal of Physical Distribution and Logistics Management*, 2003, 33, 7, p. 571.

combined analysis enables managers to quantify many of the non-financial benefits and burdens of SMI/VMI implementation and simultaneously translates performance into financial results for both firms.

The researchers stress how the success of EVA hinges on two critical elements already discussed in this thesis: accurate data interchange and trust. The article illustrates that common barriers to implementation, such as manufacturers' unwillingness to relinquish inventory responsibility to depend on the performance of an outside supplier, can be overcome by showing mutual economic benefit via the EVA model. Pohlen and Goldsby construct the model by first identifying the specific business metrics that are affected by SMI. The first diagram below maps the foundational process logic, and the second shows how the value driven benefits are manifested on a company's balance sheet.⁶⁰



Source: Adapted from Stern et al. (2001, Figure 7.2, p. 120)

Figure 31: Value drivers for achieving SMI project buy-in address key stakeholders' concerns

⁶⁰ Pohlen, Terrance, and Goldsby, Thomas, "VMI and SMI Programs: How Economic Value Added Can Help Sell the Change", *International Journal of Physical Distribution and Logistics Management*, 2003, 33, 7, p. 572-573.

EVA Component:	Effect on EVA	SMI/VMI Value Drivers:
Sales	↑	<ul style="list-style-type: none"> • Increase sales volume • Increase share of customer • Align services with cost to serve • Improve product mix • Reduce retailer stockouts • Retain profitable customers
Cost of Goods Sold	↓	<ul style="list-style-type: none"> • Improve operations productivity • Reduce raw materials costs through improved forecasts
Expenses	↓	<ul style="list-style-type: none"> • Increase forecasting responsibilities • Increase inventory management responsibilities • Reduce customer service and order management costs • Reduce sales, general and administrative costs • Optimize physical distribution • Leverage transportation and freight consolidation
Inventory	↓	<ul style="list-style-type: none"> • Reduce safety stock • Reduce cycle stock • Reduce raw materials and component inventory
Other Current Assets	↓	<ul style="list-style-type: none"> • Reduce accounts receivable • Reduce working capital
Fixed Assets	↓	<ul style="list-style-type: none"> • Improve capital investment • Increase asset utilization

Figure 32: SMI can be expected to positively impact numerous aspects of the business

The methodology proposed by Pohlen and Goldsby attempts to measure the patent benefits of SMI using standard, familiar balance sheet metrics. The EVA components listed above are common business parlance, yet the value drivers are less clearly understood by stakeholders. For example in some documented cases of SMI implementation, the raw materials cost per part actually increases for manufacturers because they must now subsidize the supplier's inventory management service. Insomuch as there might be an increase in cost, it would directly contradict the EVA value driver that material costs are reduced through improved forecasts. This exception notwithstanding the EVA methodology is an excellent attempt at quantifying the advantages realized from SMI. Main value drivers identified in the model, such as reduced current assets and inventory expenses, seem to be common benefits to other documented SMI cases.⁶¹ Not to be understated is the point that the EVA framework is not a plug-and-play model that fits all SMI processes. The vagaries of each specific case

⁶¹ Lambert, Polly, "HP Case Study: A Streamlined Vendor-Owned Inventory Management Solution", Captivate Marketing for SPC International, SPC House, Hitchin, Hertfordshire, SG4 0GG.

may eliminate some of EVA value drivers while amplifying the value-added benefit of other drivers.⁶² A powerful tool nonetheless, the EVA depiction of SMI can help achieve necessary buy-in from key stakeholders by clearly defining monetary benefits of the inventory management method via a simple, cogent framework that users can easily understand.

6 Improve

This short chapter outlines the steps necessary to populate the SMI cost v. benefit model with good data, and finishes with a few vignettes on waste reduction within the plant. Reduction of detrashing and material handling activity, work-in-process (WIP) control, automation of purchase order (PO) generation, and elimination of surplus inventory are discussed in this chapter.

6.1 Populating Cost v. Benefit Model

Ostensibly the purpose of the cost v. benefit SMI model is to identify the net changes in particular manufacturing activities between current and future states, and then dollarize those changes. Current state is defined as how inventory is now being managed; the future state is when SOI has been fully implemented. Our team developed the Raytheon financial model by collaborating with several other business areas including El Segundo, CA; Andover, MA; Wichita, KS; and McKinney, TX. Parsing the entirety of Raytheon manufacturing activity led us to separate out the constituent elements listed in the Characterize chapter. Within each bucket, or element, we identified specific activities accomplished along the process that fit into that heading. An example field from the model, Incoming Inspection, is shown below to illustrate the methodology.

⁶² Dataalliance VMI Case Study, “Business Results of Vendor Managed Inventory”, Enterprise Data Management website, www.dataalliance.net, accessed 4 November 2005.

Subcategory	Rate Type - Direct/Indirect Labor, Non-labor	RATE	How determined information	Formula / rationale in words	CURRENT STATUS				SMI				
					Total	Avg Hours per Unit of Measure	Rate for function	Dollars per part	Total	avg Hours per Unit of Measure	Rate for function	Do per	
Sample Inspection	Direct Labor Rate		Steven Strang on-site Sparton rep	n/a (Sparton is strategic supplier)									
Mechanical Inspection	Direct Labor Rate		Steven Strang on-site Sparton rep	n/a (Sparton is strategic supplier)									
Data package maintenance	Direct Labor Rate		Steven Strang on-site Sparton rep	n/a (Sparton is strategic supplier)									
Verify quality plan	Direct Labor Rate		Steven Strang on-site Sparton rep	n/a (Sparton is strategic supplier)									
Non conforming activity	Direct Labor Rate		Bruce Molinski and Mike Brookl Team Leads	Current: 192 hrs/occurrence * 2.5 occurrences/mo * 12 mo = 5.76 hrs (increases b/c now we must involve the on-site Sparton rep)	Hrs / Yr	2.5					5		
Return to supplier	Direct Labor Rate		Brenda Mitchell APX PC	Already captured in cell B10 Prod Floor (nonconforming disposition)									
Material Review Board	Direct Labor Rate		Bruce Molinski Team Lead	Current: 1 hr/wk * 50 wk = 50 hrs	Hrs / Yr	50					50		
Shipping costs	Direct Labor Rate		Lindy Kelley RTV shipping	Current: 4 Future (average not known, but activity should not make net change)									
Weekly Return to Vendor Program Meetings	Direct Labor Rate		Ed Robertson APX MRP/PC, Steven Strang on-site rep	Current: 0 Future: 3 salaried people * 80 hr/2 wks * 50 wk = 24 hrs/yr	Hrs / Yr	0					25		
Grand Totals						52.5	1.25	\$56.55			100.00		

Figure 33: The SMI cost v. benefit model data input sheets dollarize time savings for related manufacturing activities

The overall cost v. benefit model was contained in an Excel workbook, and each bucket of manufacturing activity comprised a worksheet. Incoming Inspection, shown above, included activities such as source and sample inspection, count and condition, defective material review meetings, and shipping defective parts back to the supplier. For each activity, I interviewed the stakeholder responsible persons for that task's completion to understand the time requirements involved. Let us consider the example of return to vendor (RTV) meetings. Biweekly RTV meetings in the SOI future state would be held between the APX production staff and the Acme supplier representative to determine fault and procedure for defective material. At Largo, defective CCAs are termed non-conforming material. Often detected in process on the production floor, non-conforming cards must subsequently have fault assigned. The output of the RTV meeting is the decision whether Largo or Acme is financially responsible for replacing the faulty CCA.

Traditionally, determination of fault meant that Largo would initially examine the card to determine whether it needed to be fixed, returned, or scrapped. If the card were deemed RTV it would be returned to Acme for a second examination to ascertain whether it should be fixed or replaced. Disputing fault at this second phase would be resolved by a Raytheon buyer. On the other hand, Acme would fix or replace the card if they identified themselves as the responsible party for the defect. A new or repaired card would then be sent back to Raytheon APX.

In the future SOI state, biweekly RTV meetings involving the manufacturing team lead, production controller, quality engineer, and the on-site Acme representative would streamline this process. For about 20 minutes the group would discuss the problems identified since the last meeting with defective Acme CCA cards. At that time the Acme representative could effectively determine fault and proactively screen defective cards before Raytheon sent them back to Acme's plant. Not only would this decrease throughput and troubleshooting time for Acme's quality personnel at their plant, but these meetings would also enable our team to accomplish multiple facets of the non-conforming material process, such as fault determination, in one fell swoop.

My task therefore was to roll up the tangible benefits from the new RTV process into the cost v. benefit model to compare the current state to the future SOI state. To gather the time requirement data I interviewed the manufacturing program manager, the production controller, and the on-site Acme representative. With time data in hand I plugged in the stakeholders' input into the model under the columns *Current Status* and *SMI Status* shown in the top right portion of the example screen shot above. Annualizing the time data and multiplying by the proper labor rate yielded a dollarized value of the average annual cost or benefit our group could expect from that activity's contribution to the SOI project. In this example, setting up biweekly RTV meetings with three salaried people would yield a projected annual cost of \$2,386 for the SOI project, assuming a 50-week year.

In the same manner I populated the other worksheets within the model with element time data for each genre of manufacturing activity. A time consuming exercise, completing the model involved interviewing personnel from across the plant including buyers, operators, engineers, managers, and IT and support staff. The model estimated that the total projected cost of manufacturing activity for the APX program would fall 50.2% as a result of the SOI project. Erring on the conservative side for all of the input variables, the realized benefit of the pilot effort could indeed be much greater.

The main output of the model, its cost v. benefit estimate, is shown in the program's user interface below.

Category	CURRENT STATUS	SMI	PERCENTAGE CHANGE
	TOTAL	TOTAL	
Sourcing	\$ 2,250.45	\$ 350.18	
Receiving	\$ 379.21	\$ 25.90	
Warehousing	\$ 659.32	\$ 301.85	
Factory Floor Expedite	\$ 2,322.01	\$ 312.40	
Production Floor	\$ 29.40	\$ 22.72	
Incoming Inspection	\$ 119.28	\$ 181.76	
Accounts Payable	\$ -	\$ -	
Engineering	\$ 1,136.01	\$ 227.20	
Quality	\$ 252.33	\$ 499.52	
Pack and Ship	\$ -	\$ -	
Travel Costs (Expense)	\$ -	\$ -	
Material related Costs	\$ -	\$ 650.00	
MISC - Travel, RTV, Inv sale	\$ -	\$ -	
NRE - Equipment Costs	\$ -	\$ 88.00	
NRE - Conversion Charges	\$ -	\$ 680.40	
Cost of Inventory Sale or Consignment	\$ -	\$ -	
Material Cost	\$ 11,082.11	\$ 5,711.37	
Carrying Cost Elements	\$ 17.30%	\$ 17.30%	
Carrying Cost of Material Cost	\$ 1,917.21	\$ 988.07	
GRAND TOTAL	\$ 26,145.34	\$ 10,028.37	61.5%

Figure 34: The SMI cost v. benefit model output illustrates marginal change in each activity category and displays the total estimated SMI business benefit in dollars

A graph comparing manufacturing activity cost before and after SOI is shown below; the chart is a graphical simplification of the costing trends output by the financial model. The current cost of manufacturing activity has been normalized to 100%. Therefore, if an activity costs 25% less under SOI, the chart would indicate these savings with a bar showing 75% of the normalized cost. The lines on the graph depict actual cost savings. According the axis on the right of the graph, the lines show the magnitude of the projected benefits and costs from SMI in each pool of manufacturing activity. For example the graph shows that while material cost savings are average on a percentage basis, the magnitude of dollar savings for the activity is the largest of all.

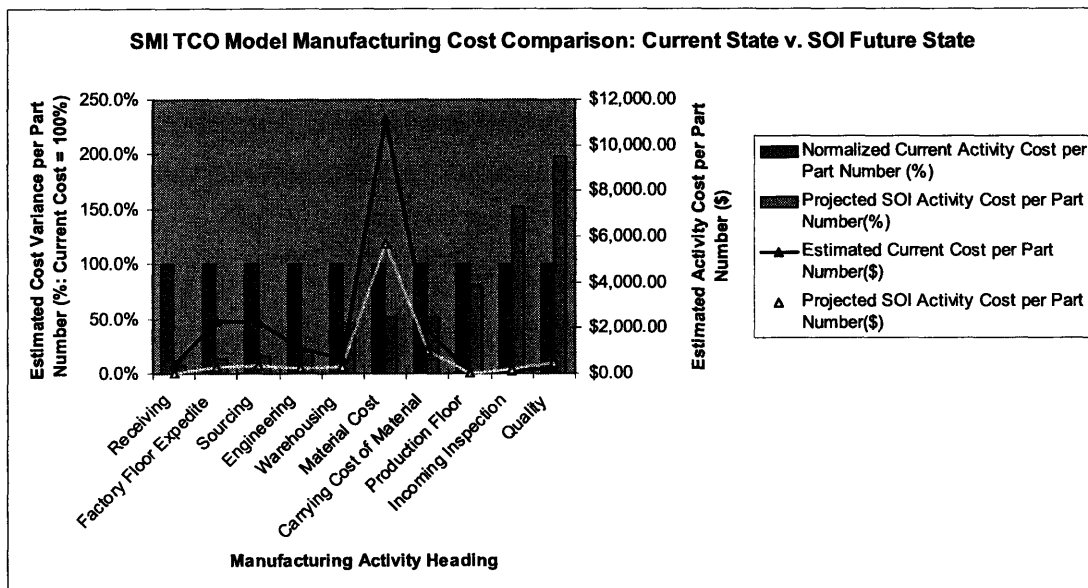


Figure 35: The APX test case illustrates a significant perceived SMI benefit

6.2 Eliminating Waste: Reducing Material Handling Activity

The material handler in the APX area is responsible for several replenishment tasks, including:

- Fetching material from general storeroom
- Replenishing workstation bins
- Storing excess delivered material in area supermarket

In the current state before SOI, the material handler would make approximately four trips per day to the warehouse. The Largo warehouse has a pick-up window where material handlers from across the plant go to receive delivered material and then bring it back to their respective manufacturing areas. When new material is delivered to the dock from a supplier, it then passes receiving inspection before being temporarily shelved in the warehouse. Certain shelves are dedicated to particular manufacturing areas, so that when a material handler arrives at the window to check on newly delivered material he only has to check his own particular shelf for boxes. It is to this warehouse pick-up window that the APX material handler walks four times per day.⁶³ There is no signal telling him that material is ready to be picked up; as a result he spaces his four trips evenly throughout the day to go and see whether anything has arrived. The nominal route he takes is illustrated below; the trip is approximately 324 ft. one-way, making a 648 ft. round trip.

⁶³ Interview with Andra' Walters, APX Material Handler, 21 November 2005.

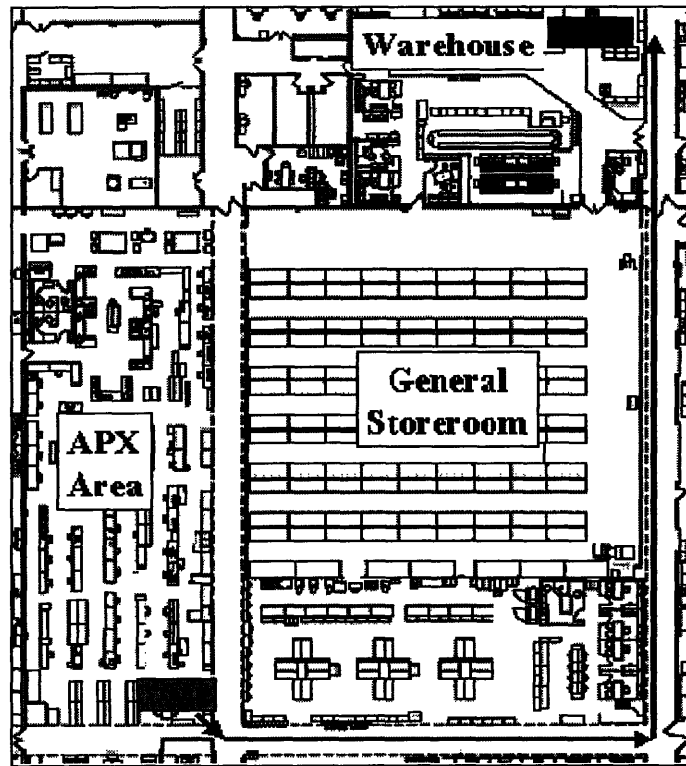


Figure 36: The material handler takes this path four times daily to check for delivered parts at the warehouse

Under the new SOI process, the Acme CCA cards would be delivered directly to the material handler's desk. Obviating a trip to the warehouse or general storeroom, the CCA boxes would move straight from the dock to the APX area. In a typical SOI agreement the supplier, Acme in this case, would be tasked with movement of material to the product line. Largo's bargaining unit contract with the UAW, however, precludes anyone but a specified bargaining unit employee from intrafactory material delivery. As a result an hourly Largo employee takes the material from the dock to the APX material handler's desk when shipments arrive. This new delivery scheme would eliminate the need for the handler to make intermittent warehouse trips to check on CCA deliveries.

On average, two of the material handler's four daily trips are non-value added; on these occasions the warehouse has no new material to pick up when the material handler

arrives there.⁶⁴ Some days there is no new material at all on any of the four trips. Under the SOI process the bargaining unit employee would only make a trip when there is material to deliver, eliminating wasteful warehouse runs.

Since our team's SOI pilot project only encompassed the Acme CCA cards, and not the entirety of the APX area's pieceparts as well, the material handler would still have to make daily trips to the warehouse to retrieve other non-SOI parts. The near-term goal nonetheless is to have the entire APX program under the SOI/SMI scheme. Assuming that the SOI process permeates the remainder of the program, eventually eliminating the material handler's need to make warehouse trips, a significant amount of wasted effort could be eliminated - a quick calculation reveals the project's potential.

Two of the four trips on average are wasteful. These two daily trips total approximately 1,296 feet of travel and 30 minutes of time wasted per day.⁶⁵ Annualizing those figures, assuming a 50-week year and five days per week, yields over 324,000 feet (61.4 miles) of intrafactory travel and 7,500 minutes (125 hours) of waste eliminated! Again, in order to reach these milestones SMI would need to be rolled out across the program.

6.3 Eliminating Waste: Reducing Detrashing Activity and Controlling Work-in-Process (WIP) Inventory on the Factory Floor

The elegance and power of the simple two-bin kanban system have been exhorted in many scholarly journals. Introduced and discussed in the Characterize chapter, the easy-to-understand method is an incredibly effective at controlling inventory levels. For this reason our team identified kanban implementation as a key component of the APX SOI project.

Moving directly to a daily kanban bin size would be too drastic for this pilot project. Traditionally Acme was replenishing material twice per month; moving to daily deliveries right away would be infeasible for at least a few reasons:

⁶⁴ Interview with Andra' Walters, APX Material Handler, 21 November 2005.

⁶⁵ Assuming the 648 ft. round trip takes 15 min. to complete, on average.

- Acme's batch building process could not immediately support single-piece flow
- Small deliveries would require Acme to carry increased finished goods
- More frequent deliveries would significantly increase shipping costs

We therefore reached the conclusion to implement weekly kanban bins. The decision was a cultural coup because we received immediate buy-in from the manufacturing staff; they would be comfortable with two weeks of inventory, held in two single-week bins, on the floor. Using the Bin-o-matic tool previously discussed in the Characterize chapter, we properly sized the bins according to forward demand data.

The pictures below contrast the current state versus our project's future vision of WIP storage on the floor. The Acme CCAs were formerly kept at the workstations in vertical racks like shown. The only signal for replenishment would be when the rack is either empty or running low on cards, at which time the material handler would add however many more CCAs he saw fit. There were no regular replenishment run rules to standardize the process, as discussed in the Visualize chapter. In this particular example, the rack has ten cards in it. The weekly bin size for this specific card is only four, as calculated by the Bin-o-matic. That means that the rack in the picture is holding two and a half weeks of inventory at the workstation.



Figure 37: CCAs are unprotected from electrostatic discharge at the workstations in metal racks

In addition, there are additional stores of CCA cards in the APX area supermarket. At times there might be several weeks of inventory for this particular card sitting on supermarket shelves like the ones shown below.



Figure 38: Significant CCA inventory stores existed in the APX area

The CCAs at the workstation and the cards within the shelved boxes, in aggregate, could easily comprise a few months' worth of inventory of any particular card at any given

point in time. To combat this surplus our team endeavored to establish an inventory control system.

To eliminate such waste and to move towards weekly kanbans our team proposed bins similar to the example shown below. These boxes would replace the metal racks above and feature foam inserts with sized partitions so that the box only holds the proper weekly amount of CCAs. There would be two of these kanban boxes in the factory: one at the workstation and one in the supermarket. The simple system would visually signal workstation replenishment, and thus supplier delivery, when the tote was empty. In addition to standardizing run rules, the two-weekly-bin kanban system would significantly decrease overall WIP by limiting overall inventory levels to under two weeks of CCAs.

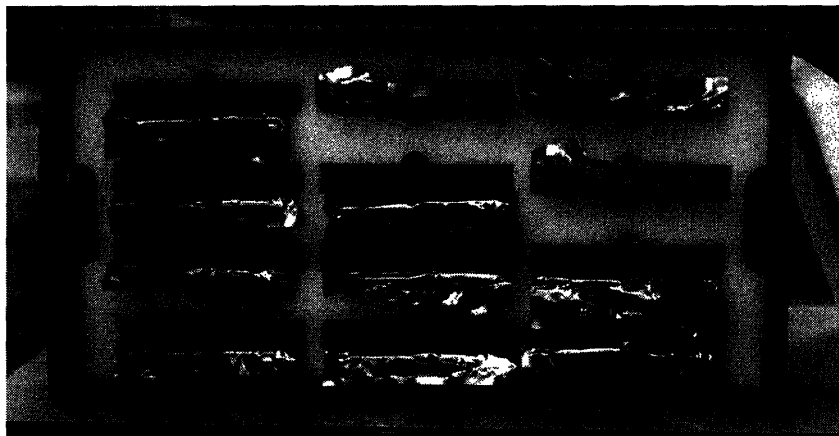


Figure 39: The foam inserts prevent replenishment of more than the required number of CCAs

In addition to controlling inventory levels, the kanban bin shown above provided three other important benefits left heretofore out of our discussion.

First, the bins allow each card to be replenished individually by type. In the Visualize chapter we discussed the workstation hangers that held two CCA racks each. We could not remove one rack to replenish it without simultaneously removing the other, since they were connected. Making it impossible to implement a proper kanban system, the racks

stood in the way of lean replenishment. By eliminating them completely, we are able to have an effective inventory control system with visual signals.

Second, the bins drastically reduce detrashing activity at Largo. Detrashing is the activity of breaking down and disposing an Acme shipping box once the CCAs have been removed from it. This action is most often completed by the material handler. The totes our team proposed above were reusable so that they could be shipped to and from Acme several times before being thrown away. Therefore, the bin in the picture takes the place of the metal racks *and* the shipping box. By serving as a reusable shipping container that can also be physically placed at the workstation, we drastically reduce the amount of detrashing activity by the material handler. On average, Acme ships the APX program 656 boxes per year.⁶⁶ These boxes are used once, meaning that APX disposes 656 boxes per year as well. If the totes we suggest were used twice, only 328 totes would need to be disposed; if they were circulated four times the program would dispose only 164 totes per year. This reduced activity makes the material handler in particular, and the process in general, more efficient.



Figure 40: Detrashing generates large amounts of waste

⁶⁶ Email interview with Bob Zimmerman, Raytheon NCS Data Manager, 16 November 2005.



Figure 41: APX detrashing activity disposes over 600 boxes per year from Acme CCA deliveries

Third, another benefit of the reusable totes is a decrease in box purchases for Acme. While packaging cost savings in this pilot project would be trivial, if reusable totes were employed in large scale across the factory suppliers like Acme would begin to see salient savings being generated.

6.4 Eliminating Waste: Automating Purchase Order (PO) Generation, Creating Pull, and Burning Off Surplus Inventory

To mirror the SMI and kanban implementation on the floor our team had to facilitate maintenance of SMI and kanban in the virtual factory, our MRP system, as well. A good place to start was with PO generation. The old MRP process of generating POs was outlined and briefly described in the Visualize chapter. Its manually intensive nature required multiple repetitive tasks, for example resizing order quantities, to be accomplished each time a PO was released. In addition the POs drove material according to MRP schedule, not according to any replenishment signal from the floor. To combat the wasted manual effort and create a kanban signal for PO generation, the process was redesigned to become more lean.

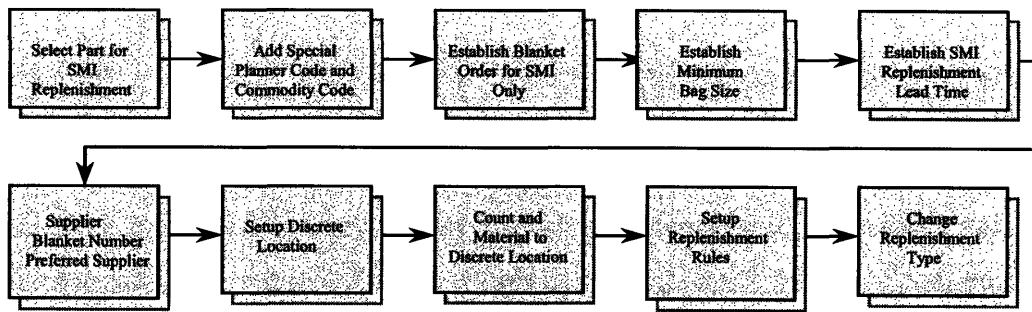


Figure 42: This one-time blanket PO setup process lays the groundwork for subsequent automation of PO generation

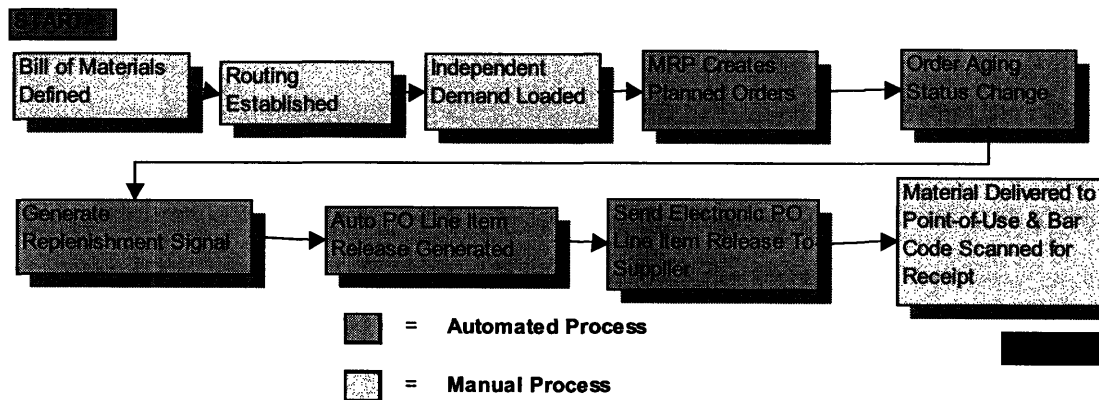


Figure 43: This automated replenishment process eliminates wasteful human intervention once the blanket PO process has been set up

The diagrams above illustrate the two pieces of the virtual replenishment process.⁶⁷ The first picture shows the blanket PO setup, or one-time manual initialization of the pull bin replenishment. When a part is first chosen for SMI and pull replenishment, this setup creates a special planner code category within MRP that denotes the part’s kanban bin size and specifies which supplier is the SMI partner for the particular part. The special category within MRP tells the system that the replenishment rules for the specific part are based on pull from the shop floor, not on push from scheduled demand. This blanket PO would be completed once per year by Raytheon procurement staff.

⁶⁷ “Point of Use Replenishment”, Raytheon NCS Largo training presentation, Chett Gear, Supply Chain Planning Manager, 10 August 2005.

The second portion of the new system, the repetitive replenishment process, allows the supplier to intermittently generate POs for us when the factory kanban signals the need for more material. When need is established the supplier enters demand into the system and the automated process exchanges electronic data between Raytheon and Acme and generates a PO. Finally Acme delivers the requisite material to Largo. The automated replenishment method is much faster and easier than repeating the myriad manual steps in the former scenario, and allows the supplier to manage a significant portion of the PO generation for us. Acme is free to initiate POs when it deems necessary during the year, and the orders all fall into the Raytheon MRP system under the annual blanket PO discussed above.

As the team redesigned the virtual material replenishment process, we had to simultaneously consider reducing the \$465 thousand worth of CCA inventory already sitting on the floor. Our bin system and its concomitant replenishment rules did not have to wait for the inventory reduction to begin. That is to say that we could use visual kanban signals with automated POs to properly control material flow *at the same time as* we burned off surplus CCAs. An added variable was the incoming material that was still being delivered from legacy POs. This inflow had to be shut off in order to make any gains in decreasing our vast existing stores of CCAs. We therefore needed to cancel or delete POs on the current time horizon. Using the existing inventory was the easy part; the harder piece was “turning off” near-term POs already scheduled in MRP.

The production personnel gave initial pushback because they wanted to ensure their receipt of material. The surplus inventory was a physical manifestation of their comfort zone, and our team was making them uncomfortable by eliminating it. Fortunately when everyone was assured of having adequate material when needed, the fears began to subside. A key enabler to the establishment of trust with the floor personnel, the process mapping discussed in the Characterize chapter allowed the production staff to see how they could buy into the new SOI process and still receive the necessary material on time. With a foundation of trust intact, the burn-off of CCA inventory began in August 2005 as

unnecessary POs were effectively removed from the MRP system. When the internship ended in December 2005 there was approximately \$240 thousand worth of CCA inventory still left in the APX area, representing a reduction of 48.5%.

7 Achieve

This chapter includes a range of topics that stem from themes in earlier chapters; the goal is to create a synthesis of various viewpoints in order to create a lucid, singular conclusion of work done during the internship. Beginning the chapter is an organizational analysis of the site using a framework coined by a MIT faculty member. Numerical results, presented as a litmus test for success or failure of the project, are then shown in conjunction with a discussion of a few incomplete steps that remained after the internship ended. Finally some recommendations for future work are discussed, and the chapter ends with a reflective discussion of the project's conclusions and important lessons learned.

7.1 Organizational Analysis: The Three Lens (Plus One) Model

John Carroll of the MIT Sloan School of Management has proposed a framework for analyzing organizational identity and effectiveness called the three lenses.⁶⁸ The strategic design lens, political lens, and cultural lens each attempt to scrutinize an organization through one pair of eyes while holding other variables constant. In such a manner, for example using the political lens, one can highlight the aspects of power and control in a business while leaving out elements of design and culture. Focusing on specific attributes with these lenses abets more intricate understanding of a limited number of variables, as opposed to superficially understanding a large host of phenomena simultaneously. One can better understand certain characteristics of a population with a focused study instead of a global study.

The strategic design lens focuses on a logical view of an organization using the belief that one can structure an organization to achieve a desired goal. An underlying assumption is

⁶⁸ Carroll, John S., "Introduction to Organizational Analysis: The Three Lenses", MIT Sloan School of Management, 2001.

that a manager can engineer an organizational architecture to be more efficacious, and that one structure can be more optimal than another. Using the strategic design lens we look at how people are grouped together to accomplish tasks through formal (e.g. business organization) and informal (e.g. personal relationships) mechanisms, and how these people's efforts are aligned with the goals of the organization at large.

The Largo organizational restructuring represented a fundamental shift in strategic design. Prior to my arrival at the site, the business was aligned according to functional responsibility.⁶⁹ For instance a scheduling support person may have been assigned to a particular product line, but all of her accountability was tied up with her scheduling function head. The functional groups were great for knowledge sharing among personnel of similar duties, for example master schedulers, however their incentives were not always aligned well with the product line management. One operations manager, for example, relayed an anecdote that when the stresses of his product line got too much to bear the functional homerooms offered a convenient and safe place where his support personnel could run and hide. Without accountability directly tied to operations, the support personnel were not always best positioned to prioritize their tasks in proper alignment with the business' overall strategy – to make quality and robust products that are delivered to the customer on time. Fortunately the value stream reorganization ignited some important changes in these key areas. Matrixing accountability for the first time would effectively split reporting duties for support personnel between functional and operations homerooms. The operations homerooms were dubbed “value streams” and attempted to better group similar products and tasks together to leverage synergies and enhance productivity. The strategic design of the organization was rebuilt to better align people behind the processes that make the business successful and profitable.

Culture is defined in the Merriam-Webster dictionary as:⁷⁰

⁶⁹ Raytheon NCS Largo Tactical Radios & Terminals organization chart, http://largo.stp.us.ray.com/largo_org.pdf, accessed June 2005.

⁷⁰ Merriam-Webster dictionary, <http://www.m-w.com>, accessed 12 December 2005

- a. the integrated pattern of human knowledge, belief, and behavior that depends upon man's capacity for learning and transmitting knowledge to succeeding generations
- b. the customary beliefs, social forms, and material traits of a racial, religious, or social group
- c. the set of shared attitudes, values, goals, and practices that characterizes a company or corporation

Culture as defined by a typical business is much harder to delineate. At its essence it is all of the elements defined above; reality however often reveals that it is much more complex and inclusive than this limited description. The cultural lens therefore endeavors to incorporate company history, beliefs, habits, and attitudes into an organizational context. Raytheon Largo has been attempting to define its culture ever since it began operations in 1998. As a consolidated manufacturing center for four disparate engineering sites, there is a confluence of culture and ideas at Largo that has made the establishment of a single identity difficult. In the aggregate view Raytheon as a whole has a deeply entrenched culture of seniority and technical expertise. Corporate reverence to seniority is visibly evident in many regards. For example the average age of all Raytheon employees is mid-40s, and at Largo in particular it is 48.^{71 72} This represents a much older demographic than most businesses.⁷³ Also, employees don medallions affixed to their company badges indicating years of service; it is not a rarity to see people with twenty-five, thirty, even thirty-five years with Raytheon proudly displayed. Finally there are periodic emails trumpeting the achievements of and awards given to the most senior employees. Technical expertise is also pervasive within the organization as the CEO Bill Swanson and numerous mid-level managers have hard science and engineering backgrounds. Largo shares many of these broader corporate traits with its own technically competent, legacy workforce. The site executive is an

⁷¹ Grillo, Jerry, "When the Time Comes", *Benefits & Compensation Solutions Magazine*, October, 2004, p. 46.

⁷² Email interview with Sang Bui, Raytheon Largo Human Resources, 14 December 2005.

⁷³ Monies, Paul, "Manufacturers Begin Taking Steps to Attract Younger Work Force", *The Daily Oklahoman*, 8 February 2005, National Association of Manufacturers website, http://www.nam.org/s_nam/sec_illum.asp?CID=201487&DID=233387, accessed 15 December 2005.

engineer by degree and training, and many employees have been with Raytheon for decades.

Unfortunately coupled with these strong positive organizational aspects are some negative traits as well. An illustrative example is the existence of stovepipes within the organization. By a stovepipe, we mean a pocket of the organization that is largely cordoned off of regular communication with other internal groups. For example the finance department may be internally proficient but outwardly isolated from the larger site, possibly due to lack of communication or cross-functional team involvement.

The new organizational overhaul has shaken some of Largo's cultural foundations at their roots. The new structure's implications for strategic design change have already been discussed; here we focus upon the cultural effects of the new scheme. Two main facets of the new value stream organization play a large role in revamping Largo's developing culture: rotational assignments and the selection process. Rotational job assignments were introduced so that employees would hold a particular job for no more than 18 to 24 months. After that time period they would be rolled forward into a different role, likely with changed responsibilities and a novel learning curve. A radical departure from the entrenched seniority that encouraged people to stay in a single role for multiple years, the constant churning of employees and roles would ostensibly enhance the company's aggregate skill set and encourage a more diverse and dynamic cultural mindset. The selection process also made waves in the traditionally placid cultural waters since it opened up every operations management job across the plant. That is to say that existing managers had to apply to the new Value Stream and Integrated Team Leader positions that were created as part of the new organizational structure. This mass shake-up was intended to facilitate the emergence of "diamonds in the rough", or undervalued employees stifled by the legacy bureaucracy. As an ancillary point, a perhaps selfish benefit of the reorganization was that the culture already had a mindset for change that made it easier to implement new ideas and achieve results for the LFM internship.

Through the political lens we view the organization as a stew of individuals whose primary motivation is to amass influence and power for oneself and one's stakeholders. The prior discussion of the strategic design lens described how venerated seniority, and thus tenure and title, is at Raytheon. With seniority come power and influence, and therefore the elder statesmen at Raytheon often wield the most authority. This approach, which seemingly purports that increased responsibility and influence at the company is only attained through extensive tenure, has left some young employees feeling stifled and underutilized. As a result Raytheon NCS has had a checkered record of young employee retention; a fact recently discussed during the quarterly business updates with current employees.⁷⁴ The company is taking appropriate steps, however, to change this reputation. Moving towards a more knowledge- and skill-based meritocracy, Raytheon has recently committed itself to matrixing accountability and updating job selection processes to empower its young high performers. The aforementioned reorganization has rewritten the rules of the game and given important contributors levers to access the upper echelons of the corporate ladder.

The title of this section insinuates a fourth lens. Ancona, et al do indeed suggest that the three-lens model is incomplete and propose a fourth lens – time, or the temporal lens.⁷⁵ The group of researchers from MIT, Harvard, UCLA, and Carnegie Mellon explain their key addition to the framework in the following passage.

“Why take on such a new lens? To make it worthwhile, the discomfort of learning a new way of thinking must be offset by some key advantage. Perhaps the best way to show this is through an example. Suppose a researcher is interested in understanding why the introduction of a new information technology system worked in one organization but did not work in another. Through a strategic design lens, the researcher comes to understand that the system worked better in an organization that was designed around teams than it did in an individually based organization.

⁷⁴ Raytheon NCS netCAST, third quarter business and people update, 5 Aug 2005.

⁷⁵ Ancona, Deborah; Goodman, Paul; Lawrence, Barbara; Tushman, Michael; “Time: A New Research Lens”, *Academy of Management Review*, Vol. 26, No. 4, 2001, p. 645-663.

Through a political lens the researcher sees that there was consensus for the change in the first company, whereas a high-level manager in the second company resisted the new technology. The cultural lens shows two different cultures - one based on experimentation and risk and the other based on rejection of new ideas and change.

In the two situations each of these lenses missed some key temporal dimensions. In the first organization the new system was introduced just as some other organizational changes were taking place. Organizational members were ready for change and were expecting their work to shift. In the second organization the new system was introduced when members were rushing to finish all of their projects by the end of the quarter. They did not feel as though they had the time to finish their work and learn a new technology at the same time.

Furthermore, members in the first organization had heard from colleagues at competitor firms that this new technology had already swept through the industry and resulted in real competitive advantage. In the second organization the technology was new to the industry and no fevered race to catch up to the competition existed. Finally, the CEO of the first organization had a very long-term planning horizon. And she saw the move to this technology as part of a larger trend to computerize particular processes. The CEO of the second organization, however, had a shorter-term perspective and was more concerned about the temporary disruption of work that the new technology would cause.”⁷⁶

Using the above example as a vehicle, Ancona, et al illustrate that the temporal lens can serve as part of an important framework for explaining and understanding organizational behavior. Offering the key advantage of the concept, the authors cite how it sharpens the methodological approach to organizational study by focusing attention on new classes of

⁷⁶ Ancona, Deborah; Goodman, Paul; Lawrence, Barbara; Tushman, Michael; “Time: A New Research Lens”, *Academy of Management Review*, Vol. 26, No. 4, 2001, p. 646.

dependent and independent variables, for example the sequencing, pacing, and duration of behavioral change. This author believes a simpler explanation is that the lens reveals the impact of time and place on change. A good change idea that is ill-timed or misplaced could fall flat or have success limited solely by time and place variables.

Viewing the organization through the temporal lens reveals the site's potential for successful change implementation in the latter half of 2005. As the first intern at a new LFM site, I did not have a well-worn path to follow upon arrival. Rather, it was necessary to blaze a new trail and to create social and political networks from scratch. Typically, implementing change is made difficult when there is an insufficient network of supportive stakeholders. I speculate that had I arrived sometime in 2004, this dearth of support may have been the case at Largo. As luck would have it the LFM internship began in June 2005, just after the kick-off of the Largo organizational restructuring in May 2005. Using the tenets of the temporal lens to focus upon the timing and placement of the internship vis-à-vis the site's organizational calendar, my arrival was serendipitously well placed. Consideration of the key variables discussed by Ancona, et al reveals why.

The sequencing was advantageous in that the LFM project began just after a large global change, in the form of a novel organizational architecture, was promulgating itself across the site. People were already freshly seasoned and ripe for change, making acceptance of my change ideas easier.

The pacing of the LFM project, which was incredibly fast due to the condensed nature of the six-month internship, also dovetailed with the in-progress reorganization. The site was restructured into value streams in just over two months' time – a brisk pace by any measure for an organization with over 800 members. Accustomed to a results-driven, accelerated tempo for change, the employees were more comfortable with my setting ambitious deadlines for goal achievement in the LFM internship. In June 2005 there was already a heightened level of healthy anxiety around the plant, making employees ready to productively contribute in a timely fashion to change implementation.

Finally, the temporal lens reveals that the internship timing was advantageous for achieving long-lasting change. My goal was to complete a project of enduring value to the company that would not die as soon as I exited the plant in December 2005. Concisely put, I intended to achieve a protracted duration of change. The reorganization in spring 2005, logically, was advertised as a permanent change. Employees were trained to understand that there was a more efficient way of making products called lean manufacturing, and that there was also a more enabling organizational structure called the value stream architecture. The clear distinction was made, and the methodological facets were compared and contrasted, between the “old” and the “new” business practices. People therefore recognized that the old regime was outmoded and the new methods were permanent. This realization imbued a sense of commitment within the culture, one that reverberated the finality of good change. It is this commitment and understanding that was advantageous to the LFM internship because people could commit to good change when they recognized its benefits. They were not fettered by antiquated ideas or outdated methods. To wit, when I proposed a method for change that showed clear benefits most people were apt to accept the new idea.

7.2 Results: Metric Improvement

To measure results of the internship project, and to illustrate the effect of our team’s changes, inventory data were analyzed in order to gauge operational impact. Even in the short term we were able to see marked improvement in key areas. Some of the most salient short-term project gains against traditional operations metrics were a result of burning off excess inventory. The charts below illustrate the downward trend in inventory we observed over the six-month time period from June 2005 to November 2005.⁷⁷ Monthly data for December 2005 were not yet available by the internship’s completion date of 16 December 2005.

The red arrows in each chart indicate the starting point of the inventory bleed down in August 2005. By slowing, and in some instances stopping, new incoming deliveries as well as better monitoring the release of raw material to the production floor WIP and total

⁷⁷ Data from Raytheon NCS Largo Webplan metrics report, accessed 5 December 2005.

inventory diminished over the course of the internship’s final few months. Dynamic cycle time is a metric that attempts to incorporate throughput levels into the classic cycle time metric; dynamic cycle time, or “WIP to ship ratio” as some operations personnel call it, is equal to the total dollar value of WIP divided by the total dollar value of shipments over a certain time period. In our example shipments per month were utilized so that the resultant dynamic cycle time units were months.

$$\text{Dynamic cycle time (months)} = \text{WIP dollar value (\$)} / \text{Shipments per month (\$/month)}$$

With decreasing WIP November 2005 dynamic cycle time decreased 34.9% compared to June 2005.

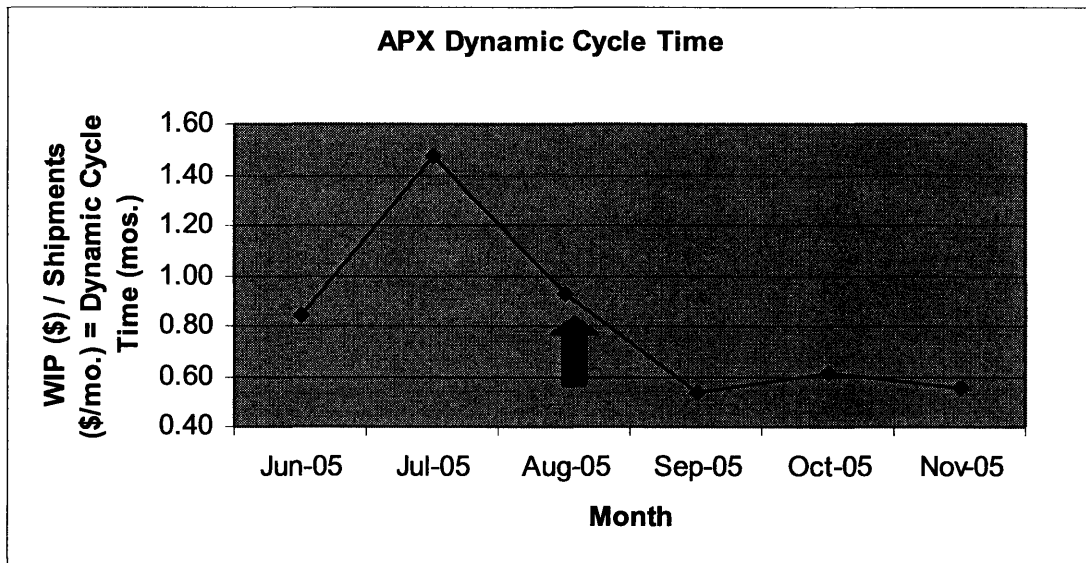


Figure 44: Dynamic cycle time for APX has been steadily decreasing since the project began

The chart below also shows that total APX inventory decreased 26.2% over the same period.

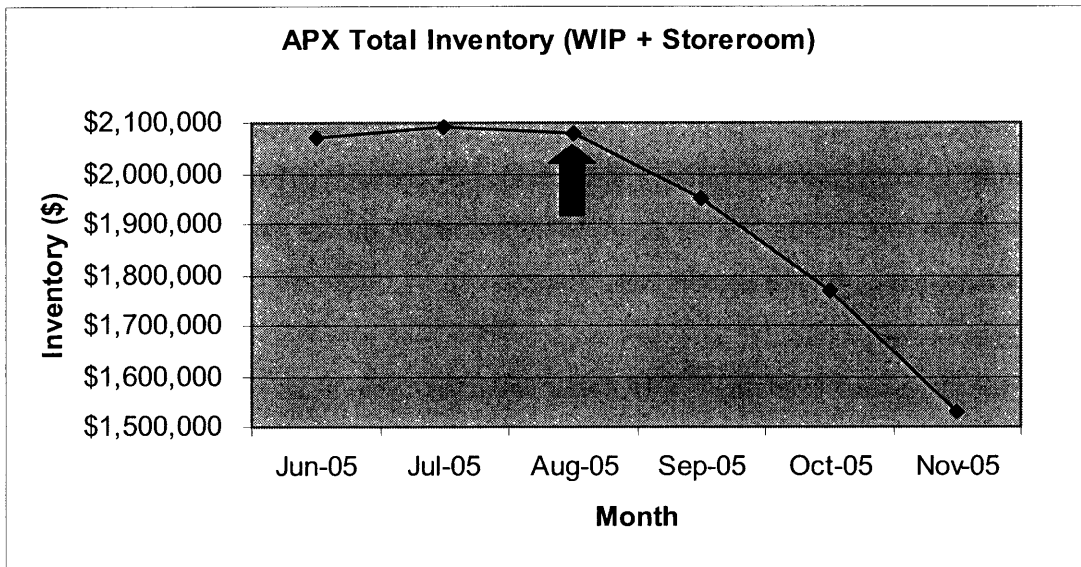


Figure 45: The inventory controls from the SOI project have decreased overall APX inventory

Annualized inventory turns is another metric used at Largo. It is calculated as follows:

$$\text{Annualized inventory turns} = 4 * (\text{sum of trailing 3 month shipments}) (\$) / \text{Total current inventory} (\$)$$

From June to November 2005 annualized inventory turns increased 76.8%. To reiterate, the largest part of these gains was achieved by slowing incoming shipments while simultaneously bleeding off excess circuit card inventory.

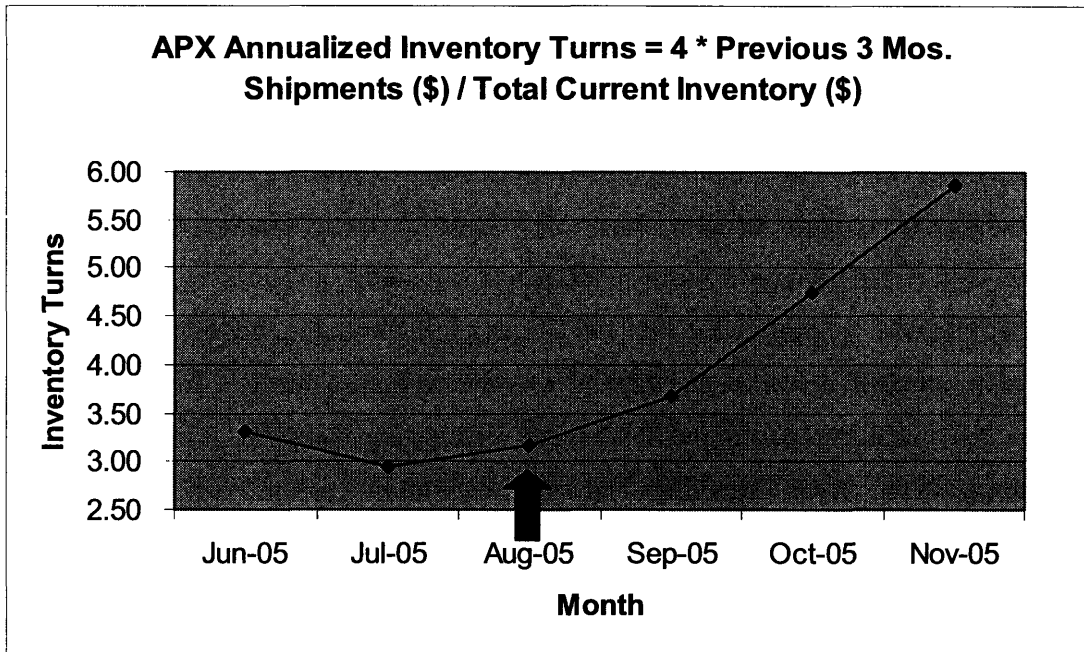


Figure 46: Inventory turns, a proxy for manufacturing health, have steadily increased over the project's lifecycle

7.3 Incomplete Steps

A key piece of the internship, the reusable kanban implementation, was incomplete at the end of the internship time period. Most of the necessary work enabling the kanban placement was complete, including the following steps:

- Achieved Raytheon Largo and Acme buy-in
- Calculated kanban sizes using forward demand data and Bin-o-matic tool
- Received reusable tote box prototypes and workstation shelving
- Showed favorable return on investment using SMI cost v. benefit model

However the final step – implementation – was not achieved. Contributing factors to this shortcoming include:

- Sample machine at supplier not functioning, needing repairs, and thus extending Raytheon's lead time for receiving reusable totes

- Raytheon facilities staff overburdened with physical reorganization of entire factory, thus extending lead time for kanban bin shelf installation

The totes took much longer than expected to arrive on site, pushing back the entire project. Buy-in could not be achieved, and Raytheon personnel would not sign up for the project, until actual prototype bins were delivered and able to be vetted by management staff. Fortunately the prototypes were delivered two weeks before the end of the internship. Pictured below are the three prototype bins that eventually arrived, and that will be implemented as part of the SOI kanban replenishment system. Also shown are the shelves on which the bins will sit and a staged photo of how the system might look once implemented.



Figure 47: The new reusable totes (left) replace the one-time use boxes (right) currently in use

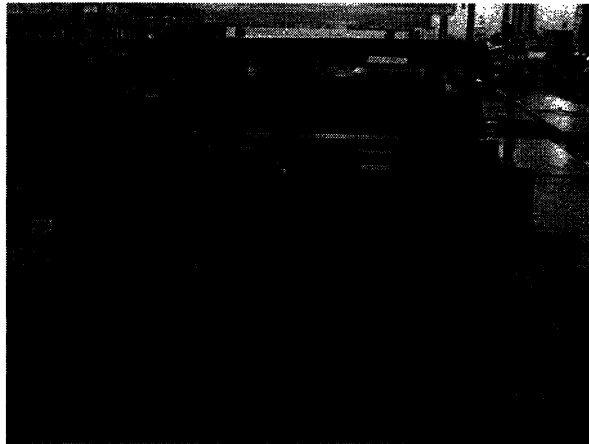


Figure 48: The reusable totes will be sized according to kanban bin quantity requirements and will limit excess inventory

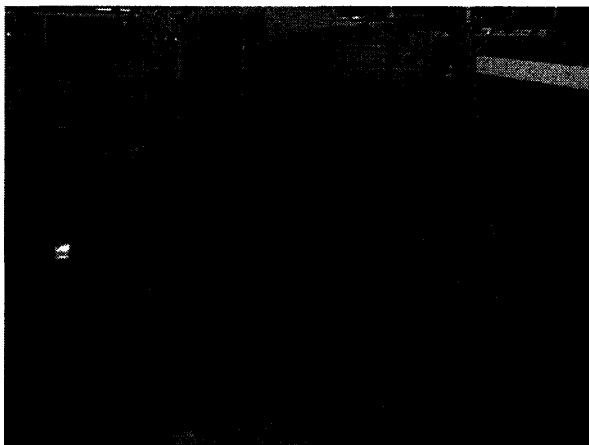


Figure 49: The bins will be kept at the workstation on shelves that the operators can easily access

Only a few remaining tasks need be completed for the reusable bin system to be fully implemented. First, the full set of kanban bins needs to be ordered from the supplier. Second, the shelves on which the bins will rest need to be installed. Finally, relevant stakeholders need to understand and agree to abide by the replenishment run rules before the system can go live. Assuming prompt receipt of the ordered bins, these steps could be completed – and therefore the system could be up and running – in less than two weeks.

7.4 Recommendations for Future Work

Of course the first recommendation for the site is to complete the reusable kanban implementation in the APX area. Coming so close to the goal in that regard without achieving it was frustrating, but the methodology for implementation is well established and the project is ready for completion in the short term. Should the APX kanban system be as successful and effective as it is intended to be, additional kanban systems can be quickly rolled out in other areas of the factory using the methodology and standardized tools from this LFM internship project to facilitate quick implementation.

A longer-term, perhaps more impactful, recommendation involves the drumbeat of the factory. Simply stated, I recommend that the site choose *one single schedule and align all people and processes behind it*. The importance of this concept cannot be overstated. Underpinning myriad problems in the factory, from the system's lack of accurate standard work times, to the untenable MRP production schedules that do not always properly account for floor capacity, and including the lack of sufficient inventory control levers, is the fact that there are multiple schedules in the factory that do not exactly match one another. At least three schedules – MRP, customer demand, and a hybrid schedule called manufacturing plan – exist at the plant, and different stakeholders are held accountable to the schedules in different ways. Though I was able to identify this issue during the internship and articulated its ramifications for the factory to the leadership team, all parties agreed that structuring a project to attack and to rectify the problem of redundant schedules would be outside the scope of my project and merit another internship entirely. Perhaps the follow-on LFM intern in 2006 could structure a project to uncover the root cause behind the multiple schedules and then suggest and begin implementation of a framework of steps to move Largo towards a single drumbeat.

This thesis has presented examples of problems arising from the lack of site commitment to only one manufacturing schedule. For instance the Visualize chapter highlighted the manual fixes that are utilized to circumvent the MRP system, internally called “line of balance” calculations. If the factory were to commit to a single schedule, MRP could easily automate these calculations and eliminate a lot of waste - in the form of excess manual work - from the process. On a greater scale, commitment to a single drumbeat

could eliminate large amounts of superfluous manual work within the plant and enhance efficiencies across a number of processes.

A second concomitant benefit of committing to a single schedule would be the improved data integrity built within Largo's various data systems. For example, if the entire plant moved according to MRP with no exceptions it would force the MRP virtual schedule to become a more accurate depiction of the factory's actual production schedule. Currently there are various buffers, for example in part lead time and standard work times, present within the MRP data hindering the system from precisely reflecting what is actually happening on the factory floor. With so many buffers present, the integrity of the MRP data suffers and people stop performing to it. Manual overrides crop up, preventing the system from doing the work it should be doing, and processes become increasingly inefficient as a result. In the future state the factory could vastly improve its productivity by choosing a single schedule, aligning people and processes behind that schedule, and continually whittling away built-in system buffers and inefficiencies to allow MRP to automate more business processes. As the "virtual factory" in MRP more closely mirrors the performance of the "actual factory", system data would become more accurate and trustworthy. Data-driven decisions, rather than manual fixes based on anecdotal experiential information, could become the norm and streamline the plant's total operation.

Hesitant to identify a problem without offering a suggestion for rectification, I conclude with the following thoughts. Two possible methods might help address the concerns above and facilitate the journey towards the future state of a single drumbeat.

First, the creation of new communication channels between key stakeholders could ease the site's shift to a single takt tempo. For example communication between the master schedulers, who load production schedules into MRP, and manufacturing managers, who ensure that the factory meets MRP production requirements, could be enhanced to ensure that the schedulers have accurate line capacity information and updates on production-related information. Currently some problems exist with MRP schedules requiring more

throughput than the factory actually has capacity to deliver, and better communication between the functions responsible for those schedules could mitigate some of the extant gaps. To the this end the Largo reorganization endeavored to create cross-functional teams, called integrated product teams (IPTs), that will include these key stakeholders and hopefully provide the proper social architecture to abet such communication.

Second, updating Largo's metrology could help drive the change towards synchronization of the disparate current schedules into a single syncopated drumbeat. Currently there are three different metrics measuring the performance of factory personnel against three different schedules. Because of the various schedules and the accountability tied into the metrics for those schedules, employees are unable to focus their efforts on performing to one single drumbeat. It would be suggested, therefore, that the site update its metrology to hold people accountable to a single schedule. Granted, this suggestion is easier said than done, but it can nonetheless be achieved to the benefit of the business and all of its stakeholders. Addressing this point in the short term, the R6s senior manager began approaching other Largo leadership members in December 2005 to initiate the process of moving towards a unified metric that reinforces a single drumbeat for the factory. In my view this simplification of metrics and focus will pay big dividends in the near- to long-term.

7.5 Project in Hindsight: Conclusions and Lessons Learned

My big takeaway from the internship was that *people are the most important part of any business process*. Underlying science behind a project can be well defined, processes vetted, and suggestions made; however nothing underpins the animus for change like the right people. In my view, during the internship's initial months it was more valuable to spend time becoming familiar with the organization than to jumpstart a more detailed process analysis in the first month. The evidence supporting this view came later in the project, during months five and six, when I needed timely help as the internship deadline approached. By that time I knew exactly which stakeholders were crucial to the project's success and where necessary information could be quickly found; my familiarity with the organization was largely derived from the experiences gained in the initial months. I am

unconvinced that the project would have gotten as far as it did towards implementation had I not known upfront the lay of the social topography.

Bolstering this view, I find it useful to add that conducting a value chain analysis at the beginning of the internship is incredibly useful for an LFM new to the organization. For instance interviewing each member of the leadership team in the first few weeks provided a wonderful introduction to the personalities and motivations of the site's key players. By understanding the mindsets of these powerful stakeholders it is easier to grasp the social physics and political landscape of the site at large. Navigating the site's social atmosphere proved to be one of the key challenges throughout the internship, and familiarizing myself with the leaders at the outset provided a huge head start to feeling comfortable at the plant. In addition it provided a mental context for my project as a whole. Since I later spent most of my project dealing with smaller details of a particular process, the initial contact I had with the strategic leaders of the plant helped me "see the whole" and bridge my "ground wars" with their "air wars" to create an internship project that would be impactful on multiple levels of the organization.

A secondary, but equally important, takeaway is that data-driven decisions are the exception, not the rule, in many businesses. Through my short experience at Raytheon I was surprised to see how many decisions are made from process frameworks that are not consistently underpinned by accurate data. Perhaps a simpler articulation is that *just because data exists does not mean that it is accurate*. Time and again, I found myself questioning certain data to find that either it was inaccurate, or it was ill-gotten by improper measurement. At times I wondered whether the organization may play a role in this phenomenon; for example if one does not foster an environment of healthy intellectual debate, would people typically be comfortable continually challenging the facts? To this extent I believe that the R6s process methodology is a boon to the Raytheon organization because it abets such data-driven decision making processes to unlock hidden efficiencies within the business.

ENDNOTES

¹ Orientation at Raytheon Sites (OARS) Overview video, <http://oars-web.stp.us.ray.com/Presentations.asp>, accessed 14 December 2005.

² Raytheon Company profile, Vault Online Career Library, http://www.vault.com/cb/careerlib/careerlib_main.jsp?cl_page=58&product_id=1028, accessed 14 December 2005.

³ Raytheon Company profile, Vault Online Career Library, http://www.vault.com/cb/careerlib/careerlib_main.jsp?cl_page=58&product_id=1028, accessed 14 December 2005.

⁴ Raytheon Company profile, Vault Online Career Library, http://www.vault.com/cb/careerlib/careerlib_main.jsp?cl_page=58&product_id=1028, accessed 14 December 2005.

⁵ SEC Form 10-K, Raytheon Company fiscal year ended 31 December 2004, <http://www.sec.gov/Archives/edgar/data/1047122/000119312505050699/d10k.htm>.

⁶ SEC Form 10-K, Raytheon Company fiscal year ended 31 December 2004, <http://www.sec.gov/Archives/edgar/data/1047122/000119312505050699/d10k.htm>.

⁷ “Welcome to Network Centric Systems Manufacturing Center” presentation, Dan Valeri, Operations Systems, Raytheon NCS Largo.

⁸ UAW and Florida UAW Local 298 websites, www.uaw.org and www.uawlocal298.org, accessed 15 July 2005.

⁹ Conversation with Peter Pisasale, Six Sigma Expert, Raytheon NCS Largo, 15 July 2005.

¹⁰ “Welcome to Network Centric Systems Manufacturing Center” presentation, Dan Valeri, Operations Systems, Raytheon NCS Largo.

¹¹ Shingo Prize website, www.shingoprize.org, accessed 15 July 2005.

¹² Raytheon Shingo feature, <http://www.raytheon.com/feature/shingo/>, accessed 14 December 2005.

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