Applying an Enterprise Architecting Framework to Design Enterprise Sales and Operations Planning

By

Brandon B. Chu

Bachelor of Science in Industrial Engineering, University of Wisconsin-Madison (2001)

Submitted to the MIT Sloan School of Management and the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degrees of

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Master of Science in Engineering Systems

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Signature of Author____
Department of Engineering Systems Division and
MIT Sloan School of Management
May 9, 2008

Certified by________________
Deborah J. Nightingale, Thesis Supervisor
Professor of the Practice, Aeronautics and Astronautics and Engineering Systems Division

Certified by____
Roy E. Welsch, Thesis Supervisor
Professor of Statistics and Management Science, MIT Sloan School of Management

Accepted by____
Richard Larson, Professor of Engineering Systems Division
Chair, Engineering Systems Division Education Committee

Accepted by__
Debbie Berechman
Executive Director of MBA Program, MIT Sloan School of Management

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ABSTRACT

Raytheon Company, a leader in aerospace and defense, has experienced tremendous growth through mergers and acquisitions. In particular, the company's Space and Airborne Systems (SAS) business unit was largely formed through acquisitions of E-Systems and Texas Instruments and a merger with Hughes Aircraft Company. To assimilate the legacy organizations, Raytheon and SAS have undertaken great efforts to work as "One Company."

One such example has been to strive for an enterprise sales and operations planning process. Five years ago, Raytheon Space and Airborne Systems (SAS) Operations leaders recognized the need to be more proactive in comprehending forecasted business and subsequent impacts to SAS' manufacturing network. As a result, Program Requirements and Operations Planning (PROP) was born to enable improved supply chain planning for factory labor and capital resources.

Over time, the complexity of SAS' business has proven to be a challenge for PROP to achieve its intended objectives. This thesis considers PROP as an enterprise rather than a process and proposes re-designing it using a holistic enterprise architecting framework including a thorough examination of the current state of PROP with respect to seven architectural views (strategy, policy/external factors, process, organization, knowledge, IT, and products/services). A future state PROP design is derived from the analysis and then validated against a detailed case study of the Army's Firefinder radar product line manufactured at Raytheon's Forest, Mississippi facility.

Thesis Supervisor: Roy E. Welsch
Title: Professor of Statistics and Management Science, MIT Sloan School of Management

Thesis Supervisor: Deborah J. Nightingale
Title: Professor of the Practice, Aeronautics and Astronautics and Engineering Systems Division

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Thank you to my classmates in the LFM Class of 2008. "Life gives us brief moments with one another… but sometimes in those brief moments, we get memories that last a lifetime."

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1. Introduction

This chapter discusses the major motivations behind the research and provides a brief outline of the thesis structure.

1.1. Motivation for Thesis

The concept of Sales and Operations Planning (S&OP) has existed for many decades, but only over the last five to ten years have companies shown a committed interest in implementing the enterprise process. S&OP's recent revival is largely driven by the increased complexity of today's supply chains. (Snow, 2005) Globalization, outsourcing, mergers and acquisitions, and more product customization are all reasons why companies have invested in some version of an S&OP process to manage customer demands and Raytheon Company is no exception to this trend.

This thesis represents research from a project completed between the months of June and December of 2007 at Raytheon Company's Space and Airborne Systems (SAS) division in partnership with MIT's Leaders for Manufacturing (LFM) program. Five years ago, SAS Operations instituted Program Requirements and Operations Planning (PROP), its version of S&OP, in an effort to be more proactive in comprehending forecasted business and subsequent impacts to SAS' manufacturing network. To date, PROP has been met with mixed results. While SAS Operations leadership would agree that their factory labor and capital planning is better with PROP than without it, analysis of the supply chain shows room for improvement.

The goal of this thesis is to use enterprise architecting principles to evaluate the current state of PROP as an enterprise rather than a process and to design and validate an improved future state. The author hopes this paper hi-lights how to approach a classical supply chain problem from a holistic, systems-thinking perspective.

1.2. Organization of Thesis

This thesis is organized into 8 chapters as outlined below:

Chapter 1 – Introduction: Describes the major motivation and goals of the thesis.

Chapter 2 – Company Background: Provides context of the business environment under which this project was undertaken.

Chapter 3 – Overview of Sales and Operations Planning: Provides context on the history, recent trends, and best practices of S&OP in industry.

Chapter 4 – Evaluation of Current S&OP at Raytheon SAS Operations: Describes PROP in detail and assesses its performance within SAS Operations.

Chapter 5 – PROP's Impact on SAS' Business Metrics: Discusses the business drivers for improving PROP including an analysis of how well SAS manages variability in its supply chain.

Chapter 6 – Designing an Enhanced PROP for Raytheon SAS Operations: Analyzes PROP through enterprise architectural views and discusses the value of the future state of PROP as an enterprise.

Chapter 7 – Illustrating PROP's Potential: Provides an example of where PROP is already exhibiting elements of the future state enterprise and how it added value to the business.

Chapter 8 – Transitioning to the Future PROP: Provides recommendations on how to achieve the future state PROP and discusses how to implement change in SAS Operations.

Chapter 9 – Conclusion: Provides a summary of key takeaways and next steps for the company.

2. Company Background

This chapter describes the history of Raytheon Company, the organization of the Space and Airborne Systems business unit, and the strategic initiatives within the company.

2.1. Raytheon Company

Founded in 1922, Raytheon Company started as an expert in the field of radio tubes becoming the leading producer of radar tubes and systems during World War II. After the war, Raytheon continued to develop and grow with the addition of its guidance missile systems business. Over the last twenty years, the company has focused on expanding through strategic mergers and acquisitions including the purchase of E-Systems (1990), Chrysler Technologies Airborne Systems and Electrospace Systems (1996), and Texas Instruments Defense Systems and Electronics (1997). Two weeks after the TI acquisition, Raytheon announced a merger with General Motors' Hughes Electronics' Defense operations (Hughes Aircraft) to form a $21 billion entity.[a]

Today, Raytheon is an industry leader in defense and government electronics, space, information technology (IT), and technical services. Acting as either a prime contractor or major subcontractor on numerous defense and related programs for the United States government, Raytheon recorded net sales of $20.3 billion in 2006.[b] The company is organized into six primary business units, Integrated Defense Systems (IDS), Intelligent Information Systems (IIS), Missile Systems (MS), Network Centric Systems (NCS), Space and Airborne Systems (SAS), and Technical Services (TS), all of which support Raytheon's strategy of providing technologically advanced and integrated mission systems to its government and commercial customers.

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[a] http://www.fas.org/man/company/raytheon

[b] http://investor.raytheon.com

2.2. Space and Airborne Systems

Headquartered in El Segundo, CA with revenues of $4.3 billion in 2006, SAS is Raytheon's leader in delivering airborne radars and processors, electro-optic/infrared (EO/IR) sensors, electronic warfare systems, space and missile defense technology, and surveillance and reconnaissance systems.[c] The majority of SAS' 12,000 employees are located across California, Texas, and Mississippi in facilities where Hughes Aircraft and TI had once maintained a presence in defense operations.

2.3. SAS Operations

SAS Operations is a strategic EMS provider for defense programs within Raytheon. Some examples of the services SAS Operations offers its customers include system/subsystem assembly and test integration, microwave antennas, platen inert gas brazing, and space-qualified manufacturing. With ~3,000 employees, SAS Operations is primarily organized as a matrix structure comprised of Program Operations and Manufacturing functions.

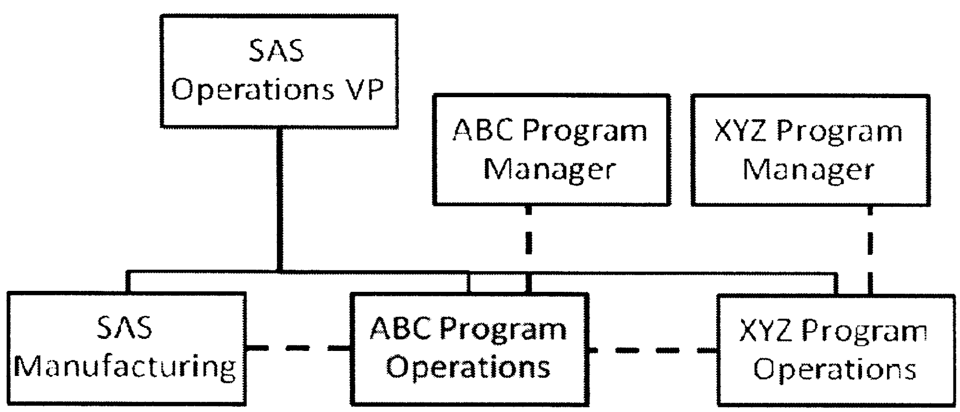

Figure 1: SAS Operations Organizational Structure

Program Operations is responsible for the relationship between SAS Operations and its customer base, and Manufacturing is responsible for competing for, winning, and performing

[c] http://www.raytheon.com/businesses/rsas

contracted work inside and outside of SAS. While Program Operations is aligned with a specific SAS business unit, Manufacturing is aligned with a specific technical capability and can support multiple Program Operations groups.

2.4. Working as One Company

Because the modern structure of Raytheon is an amalgamation of several aerospace and defense companies, the company has spent the last decade focused on uniting each of the legacy organizations into one Raytheon. As Raytheon has matured through the years, so has the interpretation of what it means to work as one company. In a 2003 internal memo to employees, Raytheon's CEO, Bill Swanson, shared his thoughts on the definition of one company.

> *Today, "one company" has evolved to mean focusing all of the strengths of our company on superior customer solutions...This definition puts the customer at the heart of what it means for us to be one company. It reinforces why it is so important that we work together (the customer wants us to). It's all about trust, sharing knowledge, and staying focused on providing superior solutions to our customers.*[d]

In this sense, PROP is a prime example of Swanson's vision of working as one company. SAS Operations leaders developed PROP with the mindset of increasing customer satisfaction and becoming a valued supplier of the programs they support. As SAS Operations' version of sales and operations planning, PROP strengthens the strategic partnership between Program Operations and Manufacturing which helps reduce program risk and cost overruns for Raytheon Company.

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[d] Excerpt from Bill Swanson's memo to Raytheon employees on July 18, 2003.

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3. Overview of Sales and Operations Planning

This chapter discusses the evolution of S&OP over time and shares current frameworks for evaluating the effectiveness of S&OP processes within companies.

3.1. Definition and History of S&OP

Widely regarded as the father of sales and operations planning, Dick Ling defined S&OP as "the integrated business planning process that provides management the ability to strategically direct its businesses to achieve competitive advantage on a continuous basis by integrating customer focused marketing plans for new and existing products with the management of the supply chain." (Ptak and Schragenheim, 2003) The idea for S&OP surfaced in the 1980s with the introduction of material requirements planning (MRP). Envisioned to be a process that enables companies to align their manufacturing operations and resources planning with the anticipated demand for their products, S&OP did not gain much corporate attention in the 1990s. (Chiappinelli, 2007) Only in the last decade has Ling's vision finally begun to catch on with the masses. Globalization, outsourcing, mergers and acquisitions, more product customization, and corporate investments in advanced supply chain planning software[e] have all contributed to the recent increased adoption of S&OP in companies.

3.2. S&OP Trends in Industry

Today, most enterprises have some form of an S&OP process in place to align supply with demand. This is what experts have coined Tactical S&OP, where stakeholders meet on a regular basis to agree on how a business plan will be implemented by operations. However, a recent study by the Aberdeen Group revealed S&OP practices are expanding beyond merely balancing supply and demand.[f] Companies now view S&OP as a useful tool for making decisions that increase a firm's profitability. The shift from Tactical S&OP to Holistic S&OP, where an enterprise's operations decisions are weighed against its business strategy, is best

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[e] AMR Research: Since 2000, companies have spent ~$12B in supply chain planning application software.

[f] The Sales and Operations Planning Benchmark Report, Aberdeen Group

supported by an updated definition of S&OP. Muzumdar and Fontanella define S&OP as a "set of business processes and technologies that enable an enterprise to respond effectively to demand and supply variability with insight into the optimal market deployment and most profitable supply chain mix." (Muzumdar and Fontanella, 2006) The key difference between Tactical and Holistic S&OP is the introduction of scenario-based modeling and the speed at which executive decisions need to be made. Instead of a single operations plan, participators of Holistic S&OP expect quick assessments of various possible business scenarios and analysis of their impacts to determine a timely response in creating, capturing, and delivering value for enterprises in a very competitive market.

3.3. Existing Frameworks for Assessing S&OP Effectiveness

The Aberdeen Group found that as a company improves its S&OP practices, key business performance metrics improve as well. As a result, companies that strive to be "Best in Class" at managing S&OP stand to gain significant advantage over a less mature competitor.

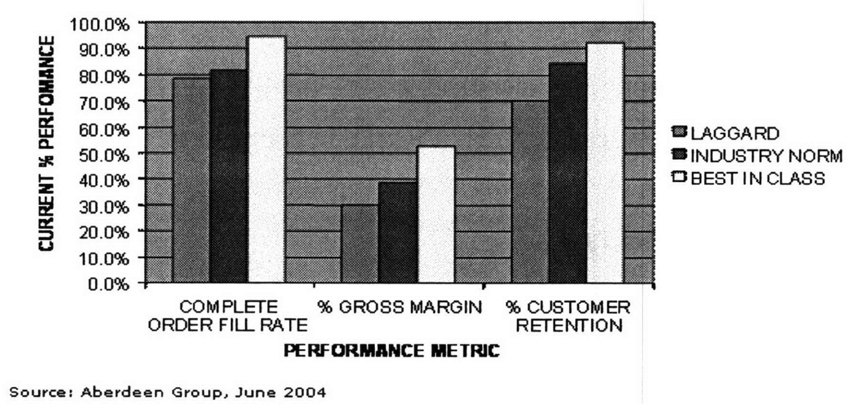

Figure 2: S&OP Impact on Business Performance

Building on the study conducted by the Aberdeen Group as well as Lapide's "Four Stage S&OP Process Maturity Model," Grimson and Pyke developed the S&OP Integration Framework from the results of research with fifteen manufacturing companies representing a cross-section of industry and size. This framework uses a one to five ranking system to classify a company's S&OP practice across the following five dimensions. (Grimson and Pyke, 2007)

1. Meetings and Collaboration – Evaluates the human dynamics in S&OP.

2. Organization – Evaluates the corporate S&OP structure.
3. Measurements – Evaluates the impact of S&OP with respect to a company's performance.
4. Information Technology – Evaluates IT's role in enabling S&OP.
5. S&OP Plan Integration – Evaluates how effectively a company builds its sales and operations plans and how well the plans interface.

Grimson and Pyke suggest that, for each dimension, a company can either be in the stage of "No S&OP Processes, Reactive, Standard, Advanced, or Proactive." The goal for a company that has implemented S&OP is to ultimately reach a "Proactive" ranking where excellence across all five dimensions translates to profit optimization. However, none of the fifteen manufacturing companies studied by Grimson and Pyke scored that ranking, and even Lapide asserts that this type of "ideal" stage is not completely achievable, and rather a benchmark for driving continuous improvement. (Lapide, 2005)

	Stage 1 No S&OP Process	Stage 2 Reactive	Stage 3 Standard	Stage 4 Advanced	Stage 5 Proactive
Meetings & Collaboration	• Silo Culture • No meetings • No collaboration	• Discussed at top level management meetings • Focus on financial goals	• Staff Pre-Meetings • Executive S&OP Meetings • Some supplier / customer data	• Supplier & customer data incorporated • Suppliers & customers participate in parts of meetings	• Event driven meetings supercede scheduled meetings • Real-time access to external data
Organization	• No S&OP organization	• No formal S&OP function • Components of S&OP are in other positions	• S&OP function is part of other position: Product Manager, Supply Chain Manager	• Formal S&OP team • Executive participation	• Throughout the organization, S&OP is understood as a tool for optimizing company profit
Measurements	• No measurements	• Measure how well Operations meets the sales plan	• Stage 2 plus: • Sales measured on forecast accuracy	• Stage 3 plus: • New Product Introduction • S&OP effectiveness	• Stage 4 plus: • Company profitability
Information Technology	• Individual managers keep own spreadsheets • Noconsolidation of information	• Many spreadsheets • Some consolidation, but done manually	• Centralized information • Revenue or operations planning software	• Batch process • Revenue & operations optimization software - link to ERP but not jointly optimized • S&OP workbench	• Integrated S&OP optimization software • Full interface with ERP, accounting, forecasting • Real-time solver
S&OP Plan Integration	• No formal planning • Operations attempts to meet incoming orders	• Sales plan drives Operations • Top-down process • Capacity Utilization dynamics ignored	• Some plan integration • Sequential process in direction only • Bottom up plans - tempered by business goals	• Plans highly integrated • Concurrent & collaborative process • Constraints applied in both directions	• Seamless integration of plans • Process focuses on profit optimization for whole company

Source: Grimson and Pyke, 2007

Table 1: S&OP Integration Framework

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4. Evaluation of Current S&OP at Raytheon SAS Operations

This chapter describes PROP in detail and baselines PROP's performance within SAS Operations using Grimson and Pyke's S&OP Integration Framework.

4.1. S&OP at SAS Operations[g]

Program Requirements and Operations Planning (PROP) is SAS Operations' version of S&OP. In an effort to manage multiple customer requests for limited manufacturing resources, SAS Operations leaders implemented PROP. The intent of PROP is to translate Program business requirements into an integrated operations plan, including Supply Chain Management and all performing functions and sites, to meet customers' needs.

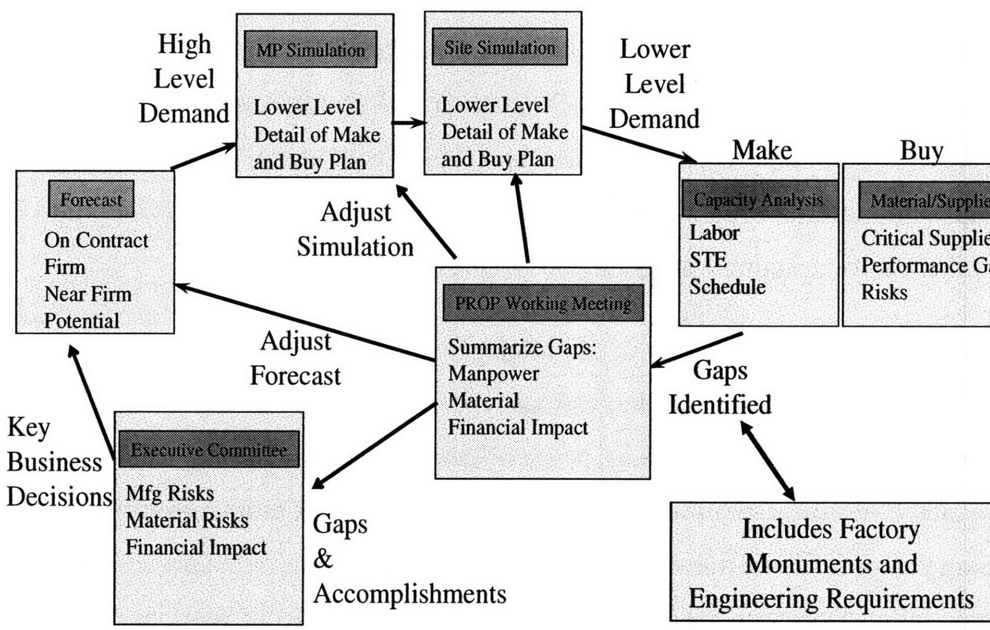

Figure 3: PROP Process Flow

The entire process occurs once a quarter over the course of seven weeks and starts with the Forecast. In this stage, Program Operations provides end item deliverable requirements (part number, quantity, and timing) to Master Planning with the forecast horizon being two years plus the manufacturing lead time of the end item deliverable. In most cases, an end item

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[g] This is Raytheon SAS Operations' account of how PROP should be, not necessarily how it actually is.

deliverable refers to the final system (e.g. radar) or subsystem assembly (e.g. antenna) requested by the customer. Demand is characterized as either on contract, firm, near firm, or potential and is based on a Program's assessment of the probability of business capture.[h]

The MP/Site Simulation stage follows the Forecast and involves Master Planning converting an end item deliverable requirement into component level requirements that will be manufactured, assembled, and tested at one or more Manufacturing facilities. During this part of the process, information such as BOM structures, material set-backs, and make-buy plans become necessary inputs. Master Planning feeds the MRP system with a consolidated Forecast and MRP generates an output file listing low level demand requirements. The file is shared with Manufacturing and Supply Chain Management in order for both organizations to complete a detailed capacity analysis.

In the Capacity Analysis stage, Manufacturing Operations Managers combine factory specific demand information from the MP/Site Simulation with factory capacity metrics to generate strategic shop load requirements for labor and capital equipment. In addition, Supply Chain Management Material Program Managers utilize the MP/Site Simulation output to determine material capacity to support program deliverables.

Once Manufacturing and Supply Chain Management complete the Capacity Analysis stage, the PROP Coordinator consolidates the various reports. The Coordinator chairs a PROP Working Meeting where Program Operations, Master Planning, Manufacturing, and Supply Chain Management representatives attend to analyze and assess risk from a factory labor and capital planning perspective. In this meeting, the Coordinator updates a factory monument[i] scorecard based on inputs from key stakeholders. In some cases, the PROP Working Meeting can result in repeating the Forecast, MP/Site Simulation, and Capacity Analysis stages.

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[h] Raytheon Company has a standard algorithm for determining the probability of business capture (PBC). PROP defines on contract demand to be 100% PBC, firm demand to be 90-100% PBC, near firm demand to be 80-90% PBC, and potential demand to be <80% PBC.

[i] A factory monument can be and is not limited to long lead time parts, unique/rare parts, space intensive equipment, high dollar capital, and specialty skilled labor.

The final stage in the quarterly PROP process is the PROP Executive Review. The PROP Coordinator is responsible for presenting the information generated over the seven week period to the SAS Vice President of Operations. Other members that attend this meeting include senior representatives from Program Operations, Manufacturing, Master Planning, and Supply Chain Management. Feedback from the PROP Executive Review impacts the Forecast stage of the next PROP cycle.

4.2. Assessment of PROP

Using Grimson and Pyke's S&OP Integration Framework as a gauge, PROP ranges from a "Reactive" to "Standard" process. Organizationally, SAS Operations does have a PROP Coordinator, but this is not his full-time job. In addition, PROP is not viewed as a full-time responsibility within Program Operations, Master Planning, Manufacturing, and Supply Chain Management. While the PROP Coordinator facilitates a PROP Working Meeting that is followed by an Executive Review, very little collaboration occurs in the Working Meeting. Furthermore, participation from Program Operations and Supply Chain Management in the Working Meeting is rare. For metrics, PROP tracks how well Manufacturing can respond to the requirements from Program Operations. However, the process lacks the ability to measure the accuracy of forecasts over time. One of the main limitations for PROP is that the IT infrastructure that holds PROP together is immature and fragile. PROP relies on manual spreadsheets that cannot be easily consolidated, cross-referenced, and archived. Lastly, PROP is still a sequential process that is driven by a "sales plan" from Program Operations and pushed through via MRP to Manufacturing.

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5. PROP's Impact on SAS' Business Metrics

Although PROP has room for improvement, the need for SAS Operations to invest in enhancements to PROP is not yet clear. This chapter examines the business case for SAS Operations to improve PROP.

5.1. Problem Statement: Why Improve PROP?

As discussed in Chapter 3, the objective of high performing S&OP should be profit optimization. Raytheon takes this notion a step further by measuring the return of a business' profit to the net assets of the business or, in financial terms, the return on invested capital (ROIC). ROIC is a key financial metric within Raytheon. Therefore, the objective of PROP is to optimize SAS Operations' contribution to SAS' ROIC. During the period of research from June 2007 to December 2007, SAS' performance in ROIC was a concern for management. While many factors impact an organization's ROIC, analysis of SAS' supply chain performance shows that PROP can do more to help increase ROIC.

5.2. SAS Operations' Position in the Value Chain[j]

Technically complex airborne radar systems that are used by the armed forces to protect and defend the nation make up a significant portion of SAS' business. The value chain for these radar systems starts with the United States tax payer as the customer. Tax payers pay for a service from the Department of Defense (DOD) or, in this case, the retailer. In turn, the DOD procures the radar from Raytheon to safeguard tax payers. Acting as a distributor, Raytheon's business units subcontract manufacturing to SAS Operations. Where SAS Operations falls on the value chain depends on whether a factory in its manufacturing network is producing a system or a subsystem. An SAS Operations' factory can build a receiver subsystem that is a part of a larger radar system that is assembled and integrated in another SAS Operations' factory. In this example of distributed manufacturing, the first factory is the supplier and the second factory is the manufacturer in the value chain.

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[j] Supply chain and value chain are used interchangeably in this thesis.

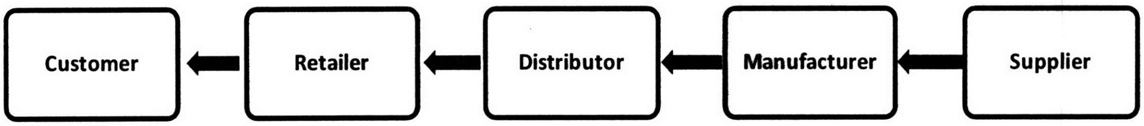
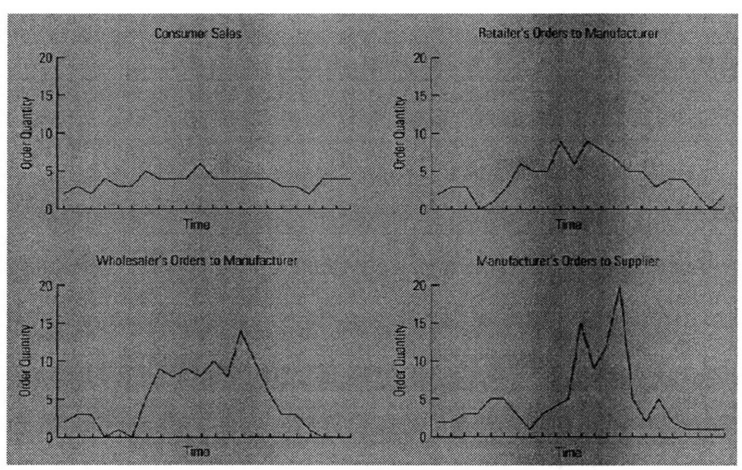


Figure 4: Illustration of the Value Chain

5.3. The Bullwhip Effect

Almost fifty years ago, Jay Forrester introduced the concept that demand fluctuation increases as one moves up the supply chain (i.e. away from the customer). (Forrester, 1961) This observed behavior is known as the bullwhip effect in supply chains since, analogous to the cracking of a whip, small changes in demand downstream of the supply chain can cause large amplifications in demand upstream. The bullwhip effect in a supply chain is a great indicator that a firm may not be achieving optimal ROIC. If a firm cannot manage the inherent variability in its supply chain, the firm will likely erode its operating margins by carrying excess inventory or stocking-out and losing potential revenue.



Source: Lee, Padmanabhan, and Whang, 1997
Figure 5: Increasing Variability of Orders up the Supply Chain

Forrester and his peers at the MIT Sloan School of Management developed "The Beer Game" in the 1960s to understand the bullwhip phenomenon. The game involves participants playing the different roles in the value chain for beer. The rules are that players cannot communicate with each other and must make order decisions using information from only the person downstream of their position in the value chain. Playing the game under these constraints, participants learn that the bullwhip effect is due to demand forecast updating, order batching, price fluctuation, and rationing and shortage gaming. (Lee, Padmanabhan, and Whang, 1997)

5.3.1. Demand Forecast Updating

Demand forecast updating refers to the action a firm takes to project demand based on what historical ordering activity it observes from its immediate downstream customer. When a manufacturer forecasts demand from the distributor, the manufacturer knows its forecast is subject to error. The inherent uncertainty in forecasting causes the manufacturer to continually re-adjust forecasts as the distributor's ordering patterns change.

The most effective way a firm can manage demand uncertainty is through lead-time reduction. Short product lead-times mean that a firm does not have to forecast demand far in advance. Open, collaborative information sharing with downstream customers and upstream suppliers has also proven to be very successful in counteracting the negative effects of demand forecast updating.

5.3.2. Order Batching

Order batching refers to the action a firm downstream in the value chain takes when placing an order with an upstream firm. To capitalize on economic efficiencies, a distributor may accumulate its demand volume for some period of time before placing an order with the manufacturer. From the manufacturer's point of view, managing demand is challenging when orders arrive in an unstable pattern.

Naturally, spreading periodic ordering evenly over time helps firms manage demand. The problem lies in how to reduce the high transaction cost of placing and executing multiple orders. The use of IT tools such as electronic data interchange (EDI) to reduce paperwork and streamline order processes has been a popular industry solution to this problem. Furthermore, coordination across the value chain is critical to ensure awareness of unique ordering circumstances.

5.3.3. Price Fluctuation

Price fluctuation refers to when a firm drops the market price for a good or service through promotions, discounts, and rebates. If a manufacturer offers a product discount, this strategy may drive the distributor to order in quantities that do not reflect its true requirements. As a result, variation in order quantity is much greater than the variation in consumption quantity.

In order to negate this undesirable result in the supply chain, firms must exercise policies to control price fluctuation. Some policies that have worked in the past include retailers implementing value pricing strategies like everyday low price (EDLP) or suppliers implementing value costing initiatives like everyday low cost (EDLC).

5.3.4. Rationing and Shortage Gaming

Rationing and shortage gaming occurs when demand exceeds supply. When a manufacturer cannot supply all of its customers, it will allocate product in proportion to the amount ordered. In response, the distributor will exaggerate its future order quantities to ensure that demand is met. This "gaming" activity masks the real demand requirements from the manufacturer and causes overproduction.

"Gaming" is a difficult behavior to curtail. Open information sharing on sales, capacity, and inventory data can help build trust and alleviate anxiety with firms across the value chain. In addition, when a genuine shortage exists, firms have switched from allocation by order quantity to allocation by historical sales volume. This reduces the incentive for customers to exaggerate orders.

5.4. Diagnosing the Bullwhip Effect in SAS' Supply Chain

Order batching and demand forecast updating cause SAS Operations to experience bullwhip effect in its supply chain. Typical SAS program lifecycles range from ten to twenty years. In this slow clockspeed industry, demand increases in a step function pattern as the program matures from development to manufacturing with order volumes staying fairly constant throughout each stage of the program lifecycle.

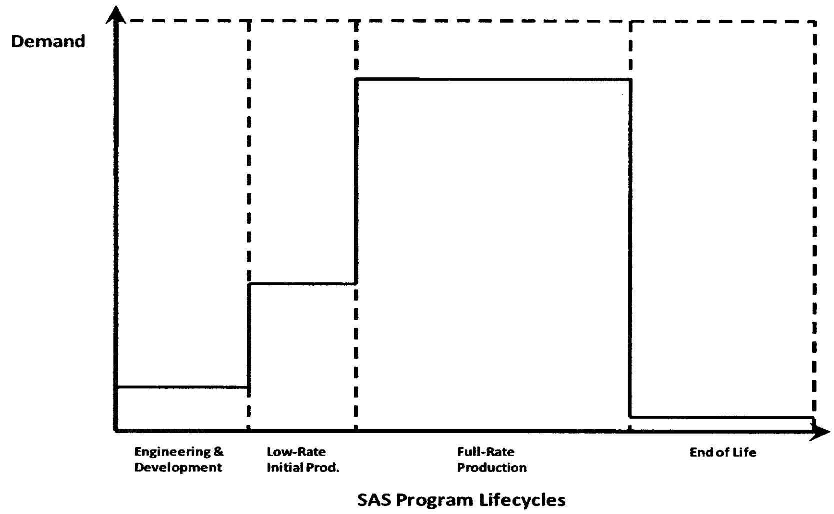


Figure 6: Change in Demand over SAS Program Lifecycles

The bullwhip effect surfaces when a program shifts from one stage in the lifecycle to another. This is because when a program progresses on the product lifecycle, funding for manufacturing increases. Analogous to order batching, programs award funding in large amounts as the program is close to transitioning into the next stage in the product lifecycle. This sudden demand spike compels a factory in SAS Operations to react with demand forecast updating.

An SAS Operations factory that produced radar subsystems for a major SAS program is a good example of this situation. In late 2005, as the program transitioned from development and engineering to low-rate initial production (LRIP), manufacturing funding increased by 144% in the span of one business quarter. As a result, this factory demonstrated evidence of significant bullwhip effect in 2006. Bullwhip effect is present when the amplification ratio is greater than one. There is more than one way to determine amplification ratios. Cachon, Taylor, and Schmidt suggest an industry's amplification ratio is the variance of its production to the variance of its demand. (Cachon, Taylor, and Schmidt, 2007) At the firm level and with limited data, Sterman defines the ratio as the maximum change in the firm's output to the maximum change in the firm's input. (Sterman, 2006) Using Sterman's definition, in 2006, the amplification ratio for the SAS Operations' factory was 3.66. In the analysis, quarterly factory shop load requirements allocated to the program in PROP were used as firm output and quarterly amounts of manufacturing funding awarded from the program to the factory was used as firm input.[k] As a tool for managing demand variability in SAS' supply chain, one can see that PROP has not been effective in controlling the bullwhip effect.

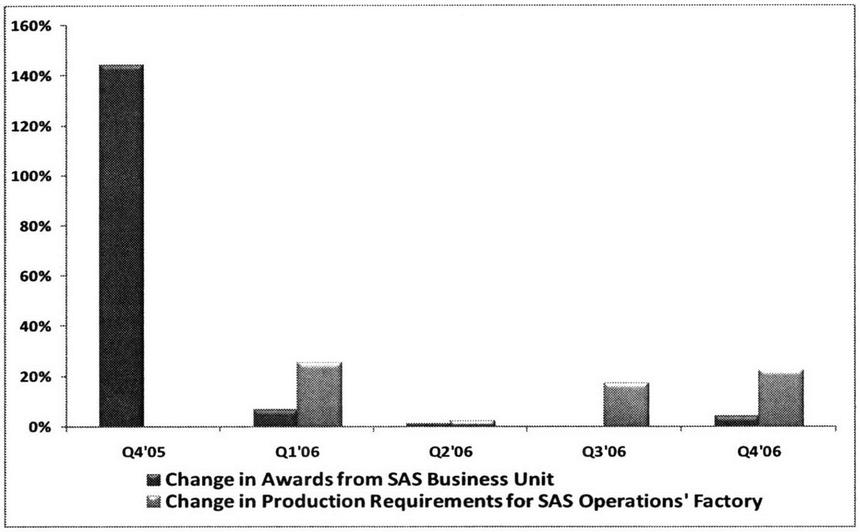


Figure 7: Evidence of the Bullwhip Effect in SAS' Supply Chain

[k] Information from Raytheon SAS Operations was limited so manufacturing funding awarded from the program was used in lieu of actual production data.

6. Designing an Enhanced PROP for Raytheon SAS Operations

The previous chapters showed that PROP has not been effective in optimizing ROIC and can be improved. This chapter explores enhancing PROP by leveraging an enterprise architecting approach to design its future state.

6.1. PROP as an Enterprise

The frameworks in Chapter 3 work well when evaluating S&OP as a business process. However, what if PROP has evolved over time from a process to an enterprise? Rouse describes an enterprise as "a goal-directed organization of resources – human, information, financial, and physical – and activities, usually of significant operational scope, complication, risk, and duration." (Rouse, 2005) In summary, enterprises are no longer simple organizations, but rather, highly complex networked structures. (Nightingale and Rhodes, 2004) Thus, by definition, one can view PROP as an enterprise where focus on the interactions between the resources of the enterprise are just as important, if not more, than the resources themselves.

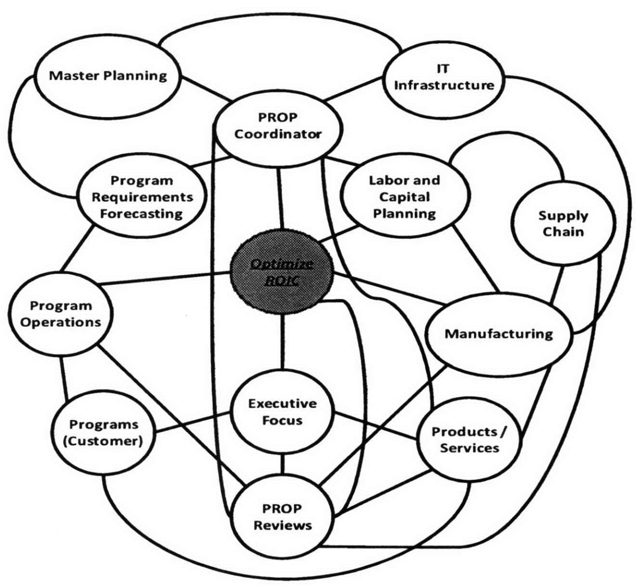


Figure 8: Current State Enterprise Map of PROP

Managing interconnected resources is a challenge for PROP as an enterprise. The tendency is to manage each resource to a local optimum which often leads to globally suboptimal results.

For example, one of the objectives for Program Operations is to develop a cost effective manufacturing plan for systems and spares deliveries. Thus, Program Operations is incentivized to negotiate with Manufacturing on the lowest quoted cost for work performed. It is not unusual for this negotiation process, also known as an Intra-Organizational Transfer (IOT), to take as much as six to eight months to complete.[l] Because Raytheon operates under a build-to-order manufacturing model, Supply Chain Management generally does not purchase material until the IOT is finalized and Program Operations authorizes the "turn-on" of Manufacturing.[m] As a result, if the IOT process experiences significant delays, any benefits that Program Operations stood to gain by negotiating a low quoted cost from Manufacturing could be negated by unexpected acceleration costs incurred for production (e.g. labor and material) or, worse yet, loss of a customer's business. For global optimization, the enterprise must balance the needs of all its stakeholders. (Nightingale and Rhodes, 2004)

6.2. Definition and History of Enterprise Architecting

In order to maximize value across interconnected stakeholders, a systems approach is needed when designing the modern enterprise. Nightingale and Rhodes define this systems approach as enterprise architecting (EA), "applying holistic thinking to design, evaluate, and select a preferred structure for a future state enterprise to realize its value proposition and desired behaviors."[n]

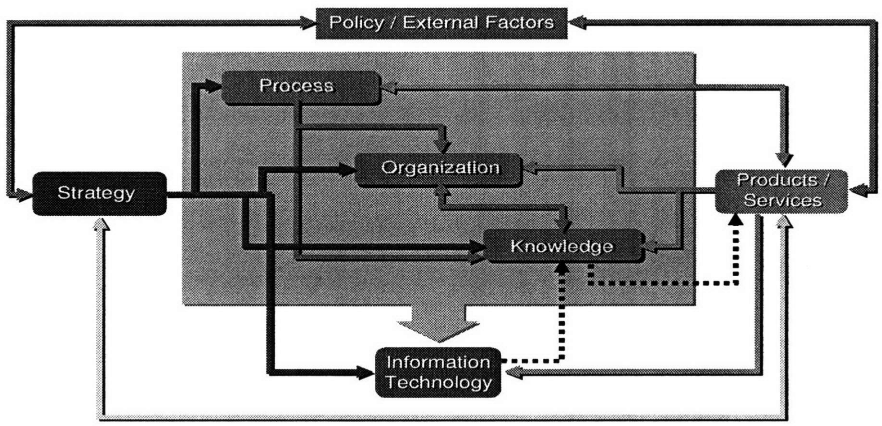
Because advanced computing and communication technologies led to the integration of traditionally stove-piped functions within an enterprise, research in the nascent field of EA has naturally taken a predominantly IT-centric view. However, Nightingale and Rhodes contend that EA requires examining the enterprise system through more than one architectural view. Their work in the Lean Advancement Initiative at MIT and development of a graduate level course on EA aims to consolidate different perspectives proposed by other researchers into an Enterprise Architecting Framework that can be used to design or re-design an enterprise. This

[l] From interviews and data collected on historical IOT quotes.

[m] At times, Manufacturing can and has received approval for a "soft turn-on" without finalizing the IOT.

[n] From the research and course notes of ESD.38J, Enterprise Architecting, Nightingale and Rhodes

framework, consisting of seven different architectural views, enables the architect to reduce the complexity of the enterprise by first breaking down the system into its collective parts and then understanding how the different parts interact with each other at a macro level. (Hebalkar, 2007)



Source: Nightingale and Rhodes, Massachusetts Institute of Technology

Figure 9: Enterprise Architectural Views and Interrelationships

6.3. PROP Through Enterprise Architectural Views

Treating PROP as an enterprise, the EA Framework is an effective tool to evaluate the current state of PROP. The following sections examine PROP through the seven EA architectural views introduced by Nightingale and Rhodes in their research and coursework.

6.3.1. The Policy/External Factors View

This view observes forces outside of the enterprise that impact strategy and product decisions. For instance, SAS was formed from key mergers and acquisitions over the last ten years. As a result, PROP is an enterprise comprised of people with different work cultures, systems with different underlying architecture, and processes with different objectives. This lack of commonality across the enterprise encourages fragmentation and the development of functional silos that end up causing suboptimal behavior in the system. To counter this behavior, SAS leadership focuses its efforts on standardization of activities, systems, and metrics across the enterprise. Another external factor is the Global War of Terrorism that has sparked an increase in demand for Raytheon's products and services in the battlefield. This change has tested PROP's ability to plan for, understand, and manage unexpected business in SAS Operations' manufacturing network. Finally, PROP is dependent on a program "being on MRP." In other words, if programs that should be on MRP do not follow protocol, then PROP would be an ineffective enterprise. In 2007, Raytheon SAS Operations developed and approved a policy that covers the minimum expectations for "being on MRP." However, adoption of this new guideline has been slow and policing the implementation is extremely difficult across a large organization like SAS Operations.

6.3.2. The Strategy View

This view represents the shared vision, goals, and direction of the enterprise. PROP shares the same strategic vision as Bill Swanson, and that is for Raytheon to become one company. At the SAS Operations level, this means that PROP, as an enterprise, needs to be integral in structure. An integrated PROP suggests that tight coordination of people and processes and strong alignment on data and technology must exist across the enterprise footprint. Currently, PROP does not exhibit characteristics of an integrated enterprise. When demand changes, PROP lacks the ability to respond in a timely manner because information hand-offs between enterprise resources are delayed. This undesirable behavior leads to suboptimal decision-making that subtracts value (decreased ROIC) for program customers. While PROP's strategy is clear, the transition to be an integral structure has been difficult to date.

6.3.3. The Products/Services View

This view examines the tangible value that the enterprise provides. SAS Operations is located in five major manufacturing facilities across California, Texas, and Mississippi. Because executive managers use the output of PROP to make important, strategic decisions impacting SAS' business performance, the enterprise must produce one informative report for management that integrates individual capacity analysis reports from all of these facilities. This report includes a summary of the current and future production capacity based on projected demand across all five facilities in SAS Operations' manufacturing network. In addition, the report captures manufacturing staffing profiles for each of the facilities. The complexity in producing this product is attributed to the inconsistency in the quality of reports from facility to facility. In this case, quality is measured by whether or not a facility provides the expected level of detail to support the generation of a PROP management report that can support sound business decision-making. For example, the aggregation of labor is typically at the facility level, but management cannot tell how labor and capital is apportioned to the SAS business programs.

6.3.4. The Information Technology View

This view examines the role IT plays as an enabler of processes, organization, and knowledge transfer within the enterprise. Since 2005, Raytheon SAS has been undergoing a large-scale IT transformation. At the center of this transformation is the implementation of an enterprise resource planning (ERP) system beginning with the organization's financial processes. Raytheon dubbed the supply chain and manufacturing suite of the ERP system as PRISM. Once SAS Operations completes its conversion to PRISM in 2008, 75 out of 120 operations oriented applications will be retired including the unification of four facilities under one common MRP system and IT architecture.[o]

Raytheon SAS' IT transformation represents a tremendous opportunity for PROP in its journey towards an integral structure. A good example of where IT can help improve the enterprise is with Program Requirements Forecasting. PROP receives forecasts from several (>10) Program Operations Managers. A limitation of the current IT infrastructure is that SAS Operations' MRP systems do not archive consolidated PROP forecasts. Thus, PROP cannot measure its forecast accuracy over time. SAS' strategic IT roadmap includes leveraging proprietary advanced supply chain planning applications[p] that mesh well with ERP systems. These applications are designed to specifically handle S&OP type activities such as demand management.

These advanced supply chain planning systems can also help with capacity planning. SAS Operations does not have a standard capacity planning system. Instead, each factory in the

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[o] One SAS Operations facility is not on Raytheon SAS' ERP conversion roadmap.

[p] Note the global enterprise strategy is an integral structure, but the local IT strategy can be modular.

operations network relies on fragmented "home-grown" systems (e.g. Excel workbooks and Access databases) to perform analysis of factory resource requirements. In 2007, the SAS' Consolidated Manufacturing Center (CMC) in El Segundo, California created a proof-of-concept Capacity Modeling System[q] that serves as the vision and reference for how to develop a centralized capacity planning system for all of SAS Operations. However, the tool was developed using a combination of Access, Excel, and Visual Basic, and the model's likelihood of long term sustainability is low. For the concept to survive, this tool must be transported into an application environment that will have dedicated development resources and is an integral part of SAS' strategic IT roadmap.

6.3.5. The Process View

The process view consists of the core processes by which the enterprise creates, captures, and delivers value for its stakeholders. Nightingale identified three types of processes in an enterprise – life-cycle processes, enabling infrastructure processes, and enterprise leadership processes. Life-cycle processes refer to the value stream of activities that contribute directly to the creation of products, systems, or services delivered to the enterprise's customers. These processes have historically been the main focus of a company's process improvement initiatives, but from an EA perspective, the other two are just as critical. Enabling infrastructure processes support the execution of enterprise leadership and life-cycle processes by providing supporting services to each organizational function and its internal customers. Lastly, enterprise leadership processes are developed and maintained by leadership to guide the activities of the enterprise and involve offering direction and resources to break down barriers among and within life-cycle processes in order to create increased value to customers and stakeholders. (Allen, Nightingale, and Murman, 2004)

[q] This capacity model was the end product of a Raytheon sponsored summer internship of three students from the University of Michigan's Tauber Manufacturing Institute.

Life-cycle Processes	Enabling Infrastructure Processes	Enterprise Leadership Processes
• Forecast • MP/Site Simulation • Capacity Analysis	• Intra Organizational Transfers • Materials Requirements Planning • Bill of Materials Management	• PROP Working Meeting • PROP Executive Review

Table 2: PROP's Enterprise Processes

As enterprise lifecycle processes, the Forecast and MP/Site Simulation processes should focus on standardization. The PROP Coordinator defined an Excel template for Program Operations Managers to follow, but quarterly spreadsheet forecasts rarely resemble the original template. For some programs, the forecast is just an e-mail with a list of end item part numbers and delivery schedules. The lack of Forecast format standardization and process conformance leads to ambiguity, delays, and workarounds in the enterprise value stream which, consequently, impact product quality. In the case of MP/Site Simulation, PROP does not have process uniformity across the five manufacturing facilities. Because, SAS Operations used multiple MRP systems, Master Planning is decentralized which allowed sites to control the information shared with PROP. As a result, PROP's low level demand plan excludes projected near firm and potential demand if sites chose to suppress this information from the enterprise. The research uncovered that at least two major facilities did not share near firm and potential demand with PROP.

Currently, enabling infrastructure processes require the most attention in PROP. The IOT process does not add value to the end customer, but is necessary for financial accounting purposes to document the scope of work contracted to SAS Operations' facilities. From a value stream mapping perspective, the enterprise should have tremendous incentive to reduce the process cycle time. However, as mentioned earlier, the IOT process can take several months to complete and incentivizes programs order batching in the supply chain. Furthermore, MRP is an integral component of PROP and the MP/Site Simulation process suffers when the global MRP policy is not followed. Thus, clear expectations of when and how MRP will be used as well as strict enforcement of those expectations across SAS Operations is absolutely critical to the enterprise. Lastly, Factory Capacity Planning is decentralized across SAS Operations. As a result, each factory has slightly different rules around strategic and capacity management depending on the manufacturing philosophy of management at the different sites. Developing a centralized Factory Capacity Planning process is extremely difficult and may not be possible since factories within SAS Operations may have fundamentally different operating models. For example, a large volume of business for the circuit card assembly (CCA) shop in El Segundo, California is walk-in work for engineering and design. However, the CCA shop in Forest, Mississippi is primarily dedicated to steady-state production. How each factory manager manages capacity for his or her respective businesses is vastly different.

Within the enterprise, the PROP Working Meeting is one of the most important processes. As an enterprise leadership process, the PROP Working Meeting must focus on creating increased value for enterprise customers and stakeholders. The Meeting can achieve this by enabling the development of a comprehensive, quality product that integrates and distills information at a level for SAS' operations leaders to make good management decisions. In order to accomplish this objective, the process has to have active cross-functional participation (Lapide, 2004) from, at a minimum, Program Operations, Master Planning, Manufacturing, and Supply Chain Management. Today, the Working Meeting is not run in this manner. Instead, the Working Meeting is a forum where each SAS Operations factory will report out on the results from the Capacity Analysis process. As a result, the Working Meeting has lost its working element since the other functions of Program Operations, Master Planning, and Supply Chain Management are not often represented. Furthermore, the role and seniority level of the representative from the factory is not standardized. One factory may send an industrial engineer to speak to the results, while another may send a manufacturing manager.

6.3.6. The Organization View

This view represents organizational structure as well as relationships, culture, behaviors, and boundaries between individuals, teams, and organizations. As a virtual enterprise, PROP is functionally structured between Program Operations, Master Planning, and Manufacturing. Although PROP's intent was to include Supply Chain Management's input into the operations planning activity, the author did not observe any active participation from Supply Chain Management throughout the PROP process.

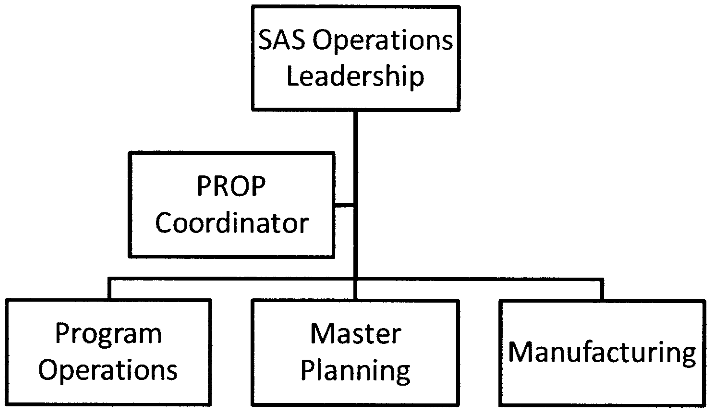

Figure 10: PROP Enterprise Organizational Structure

The PROP Coordinator oversees the activities of each of the three functions and delivers regular reports to management on the status of each function's activities. Ultimately, Program Operations, Master Planning, Manufacturing, and the PROP Coordinator all roll up to SAS Operations Leadership which is, for the most part, very supportive.

The problem with this stove-piped organizational structure is that it does not promote collaboration amongst the three core functions. Program Operations, Master Planning, and Manufacturing do not work together as an integrated PROP team to jointly develop forecast requirements, demand plans, and capacity analysis reports. PROP follows a linear workflow design with work performed by each function and passed on downstream for the next function to address. The risk with this behavior is it intensifies the impact of demand forecast updating on the bullwhip effect because by the time Manufacturing receives work that originated from Program Operations, the demand information may be dated and require a refresh. Given PROP's seven week cycle time, this is a real issue the enterprise must deal with to avoid inaccurate operations plans.

A major reason why PROP's core functions perform work independently is because communication barriers exist. More specifically, fundamental business terms like "Program Name" do not share the same interpretation across enterprise functions. For Program Operations, "Program Name" refers to a major program in SAS (e.g. F-15). For Master Planning, "Program Name" refers to the name of a project that the program business is planning (e.g. F-15 Upgrade Bundle 1).[r] For Manufacturing, "Program Name" refers to a customer that the factory serves (e.g. F-15 AESA) and is typically slightly more specific that the "Program Name" used by Program Operations. Because language is not standardized, PROP's core functions continue to operate in stove-pipes.

6.3.7. The Knowledge View

The knowledge view encompasses the implicit and tacit knowledge, capabilities, and intellectual property resident in the enterprise. Raytheon, as a large enterprise, puts little focus on this architectural view. Knowledge transfer between business units (e.g. Integrated Defense Systems to Space and Airborne Systems) rarely happens. A company artifact that supports this notion is, up until December 2007, [s] a Raytheon corporate intranet webpage did not exist. Instead, a SAS employee that opened up his or her internet web browser would be directed to a SAS specific intranet homepage.

Knowledge transfer is also an issue at the PROP enterprise level. Only a handful of individuals completely understand what PROP is and how it works. In conversations with SAS Operations leaders, many of them often referred to PROP as a "database" that "IT can hook into" to extract consolidated demand plans and this is clearly not the case. PROP is often misrepresented because stakeholders are not educated on the enterprise and they do not know who, other than the PROP Coordinator, to seek for help with their questions. A larger issue is the archiving and retrieval of PROP related data. Only recently has the enterprise begun to use knowledge sharing tools like eRoom to store program requirements and capacity analysis reports. Organization-wide adoption of this new practice has been slow. In order for PROP to truly be institutionalized, emphasis needs to be put on formalizing tacit knowledge through more detailed documentation, on-going training, and IT systems utilization.

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[r] This is an example and not a real project name.

[s] In December 2007, Raytheon launched a company-wide intranet homepage called Portal.

6.4. The Future PROP Enterprise

After breaking down the enterprise into seven architectural views, two complementary themes emerged for enhancing PROP – organizational integration and process standardization. These central themes are then reinforced by investing in enterprise enablers like IT and knowledge management. Focus on these key areas will increase the agility and flexibility of the future PROP enterprise.

For design purposes, it is important to distinguish between agility and flexibility. Agility is how fast the enterprise can respond to change. On the other hand, flexibility is the ease (e.g. cost and time) and degree with which the enterprise can shift its focus and priorities. (Baker, 1996) When considering the future state of PROP as an enterprise, both are equally important.

Increased agility is achieved through organizational integration. PROP's product, an informative management report that enables sound SAS Operations decision-making, is integral and complex, composed of inputs from various resources across the enterprise. Thus, the future PROP enterprise should adopt an integrated approach to product development. In this sense, Program Operations, Master Planning, Manufacturing, Supply Chain Management, and Finance become an integrated product team (IPT). In addition, an effective PROP Working Meeting serves as the forum and structure for the IPT to jointly manage the product development process from conception to customer delivery. (Allen, Nightingale, and Murman, 2004), IPTs have proven to be an effective method to reduced product rework and development cycle time. Rather than independent stove-piped functions processing work and passing it on to the next function, the IPT forces these organizational silos to work together, generates "creative tension," and surfaces issues early in the product development process. This results in a high quality final product – a management report that contains accurate information to drive improved supply demand management at the factory level and increased ROIC for SAS as a whole. The next chapter shows how a factory in SAS Operations, through this exact approach, increased PROP's agility and achieved great results.

The Toyota Production System is a great example of how increased flexibility is achieved through process standardization. (Spear and Bowen, 1999) The production flexibility Toyota gained enabled it to diversify its product portfolio so that it now competes in many segments of the market.[t] Similar to Toyota, PROP has opportunities in the future to add value beyond its current product offering. PROP is uniquely positioned to provide a comprehensive demand plan that includes awarded and projected (firm, near firm, and potential) business. Support organizations like Supply Chain Management and Finance have expressed heavy interest in being able to leverage PROP's services as a one-stop shop for inputs into material spends forecasting and analysis. Raytheon recognizes revenue using percentage-of-completion accounting where a business unit's sales and profits are based on the ratio of program's actual cost incurred to the program's total estimated cost at completion. As a result, one can see why Supply Chain Management and Finance would like to find easier ways to project and track how much a program is spending on material. Unfortunately, inconsistencies in the quality of PROP forecasts leave the enterprise short of delivering this value to Supply Chain Management and Finance. Furthermore, the data required for material spends forecasting is the output from PROP's MP/Site Simulation process which, today, is fragmented and lacks key data (near firm and potential demand) from some of SAS Operations' facilities. To capitalize on this strategic opportunity, PROP should emphasize the standardization of the Forecast and MP/Site Simulation process (expectations, metrics, roles, and tools) with Program Operations and Master Planning. Once processes are standardized and understood, IT (e.g. PRISM) and training can help with process sustainability in the enterprise.

[t] Toyota Motor Company started out as low price automobile manufacturer.

7. Illustrating PROP's Potential: Case Study on SAS Operations' Forest, Mississippi Facility

The future state of PROP described in the last chapter exists in SAS Operations, albeit in small pockets of success. This chapter describes in detail one such success story within the organization.

7.1. The Forest Facility

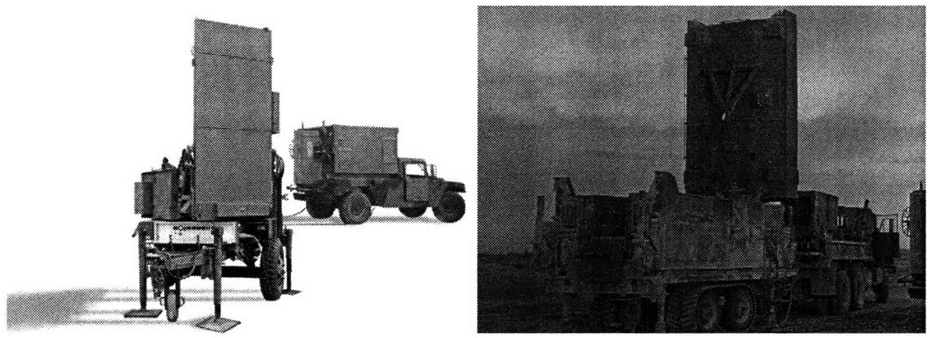
In 1983, the Sunbeam Company closed its clocks and appliances plant in Forest, Mississippi. Shortly afterwards, Hughes Aircraft Company assumed operations of the facility and began producing CCAs and cables. By 1988, Forest's operations included production of Navy ADCAP torpedoes as well as CCAs. Over time, Hughes Aircraft expanded its Forest manufacturing footprint to 22,000 square feet and helped grow the high tech job sector in Mississippi. (Yarbrough, 1991) In 1996, Hughes Aircraft added ground-based battlefield products starting with the Army's Sentinel radar system followed by the Firefinder radar system. In 1997, Hughes Aircraft merged with Raytheon. By 1998, Forest was a major part of SAS Operations' manufacturing network.

7.2. Forest's Products

Today, Forest is viewed by Raytheon programs as a competitive producer of integrated radio frequency (RF) and electro-optic (EO) systems and subsystems. Forest's product portfolio consists of airborne radar systems, ground-based radar systems, radios, electronic warfare systems, and electro-optics.

7.2.1. The Firefinder Radar System

The Firefinder family consists of the TPQ-36 and TPQ-37 ground-based mobile radar systems. Manufactured for the U.S. Army Communications-Electronics Command (CECOM), the TPQ-36 and TPQ-37 systems serve different combat purposes. With a replacement cost of ~$1.5M, the Army uses the TPQ-36 system to detect and locate hostile mortar, artillery, and rockets at short to medium ranges. On the other hand, the TPQ-37 can cost up to $6M depending on Army requirements and is used to detect and track hostile mortars, artillery, and rockets at long distances that are sometimes even past those weapons' maximum effective ranges. In addition, the TPQ-37 has the capability to distinguish between enemy and friendly fire.[u]



Source: http://www.raytheon.com/products/

Figure 11: TPQ-36 (Left) and TPQ-37 (Right) Firefinder Radar Systems

7.3. The Bullwhip Effect in the Firefinder Spares Supply Chain

Developed in the early 1970s, the Firefinder Radar System has served the United States Army for many years. While production of new TPQ-36 and TPQ-37 systems for the Army ended in 1986, ThalesRaytheon Systems[v] (TRS) has been supplying spares for field units as well as engaging in sales of new systems to foreign military. Since TRS is not a Raytheon business unit, TRS subcontracts manufacturing to Forest via an intermediary Raytheon business unit, Network Centric Systems (NCS), that oversees the IOT funding process. In turn, Forest secures the labor, capital, and material from suppliers to build, assemble, integrate, test, and deliver Firefinder systems and spares. Up until late 2004, Forest observed small order volumes for spares with little variability in demand from TRS. However, the Global War on Terrorism changed customer behavior and created a tremendous demand spike in the Firefinder spares supply chain.

In November 2004, TRS and the Army signed an urgent contract calling for the production of more than 3,500 spare and repair parts (over 100 part types) to maintain Firefinder radars in the

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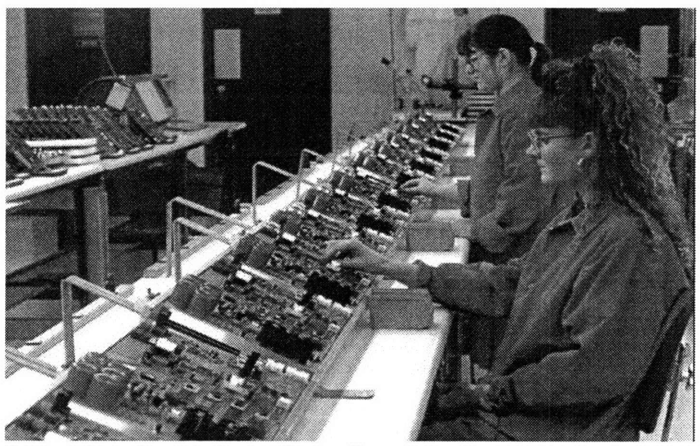
[u] TPQ-36(V) and TPQ-37(V) radar forecast from http://www.forecastinternational.com.

[v] ThalesRaytheon Systems is a joint venture between Raytheon and Thales Systems.

battlefield.[w] Almost 70% of the spare part volume ordered consisted of printed circuit boards (PCBs) for Firefinder systems in the field, and Forest's CCA shop specializes in through-hole assembly of PCBs. Through-hole assembly involves inserting component parts into holes on a PCB and soldering the component leads to the PCB track. While production can be automated with equipment, the CCA manufacturing process for Firefinder products in Forest is primarily a manual operation designed for high-mix, low volume production. To meet the unexpected surge in spares demand, Forest factory managers needed to increase the manufacturing capacity of the CCA shop. This meant adding build stations and hiring skilled labor to perform the forecasted work.



Source: http://www.altronmfg.com/images/sce/lowvolume.jpg

Figure 12: Example of Manual Through-hole Assembly of PCBs

By January 2005, Firefinder spares awards from NCS increased by 138% from October 2004. Six months later, funding to produce these desperately needed spares jumped another 137%. After June 2005, Firefinder spares orders from NCS slowed down for nine months, but the order batching and subsequent demand forecast updating led to bullwhip effect in the supply chain. Again, using Sterman's definition, during the time frame of June 2005 to March 2006, Forest's amplification ratio was 1.90.

Evidence of the bullwhip effect alerted Forest management that PROP was not acting fast enough to identify customer needs. Although the first demand signal came from NCS in late 2004, the corresponding supply requirements did not show up in PROP for another six months.

[w] TPQ-36(V) radar forecast from http://www.forecastinternational.com.

This left the factory short of adequate production capacity to support the increased demand. Furthermore, Forest was constrained by a surprised supply base that was not ready to support the sudden shock in demand. Supplier lead times were too long to support the spares delivery requirements and supplier parts obsolescence issues also surfaced. By the end of 2005, Forest was scrambling to deliver an unprecedented amount of Firefinder spares.

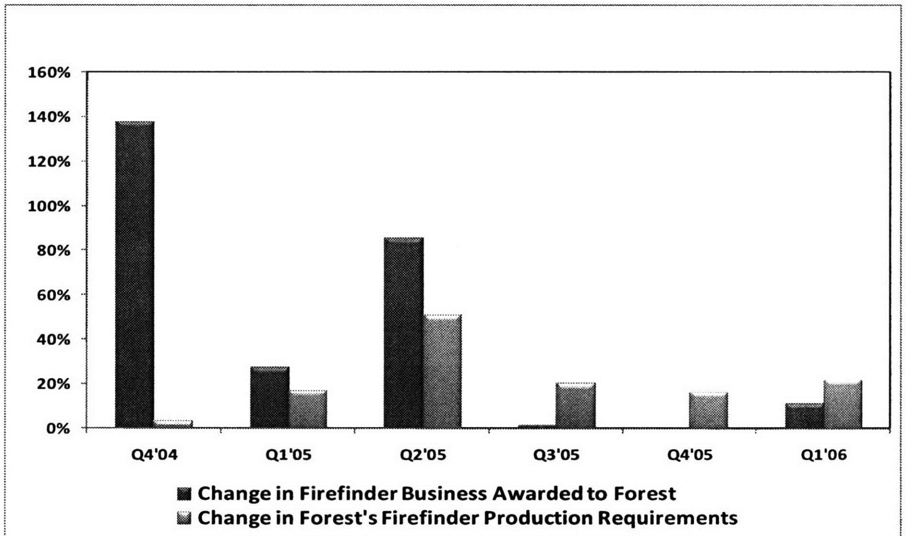


Figure 13: Bullwhip Effect in the Firefinder Spares Supply Chain

7.4. Forest's Response to the Problem

In March 2006, Forest received another delivery order for more Firefinder spares. Award funding from TRS jumped up 60% from January 2006. This time PROP was better prepared to counteract the bullwhip effect. In particular, one of several strategic actions Forest factory management took was to structure PROP so that it could be more responsive to managing demand changes. In summary, Forest transformed PROP from a modular process to an integrated enterprise. As a result of this strategic shift, PROP became more agile in responding to another demand lump. In the months following the increase in spares delivery orders, the amplification ratio dropped from 1.90 to 1.35. In the words of the Forest Site Manager, TRS, NCS, and SAS were "were working to implement a total Raytheon solution."

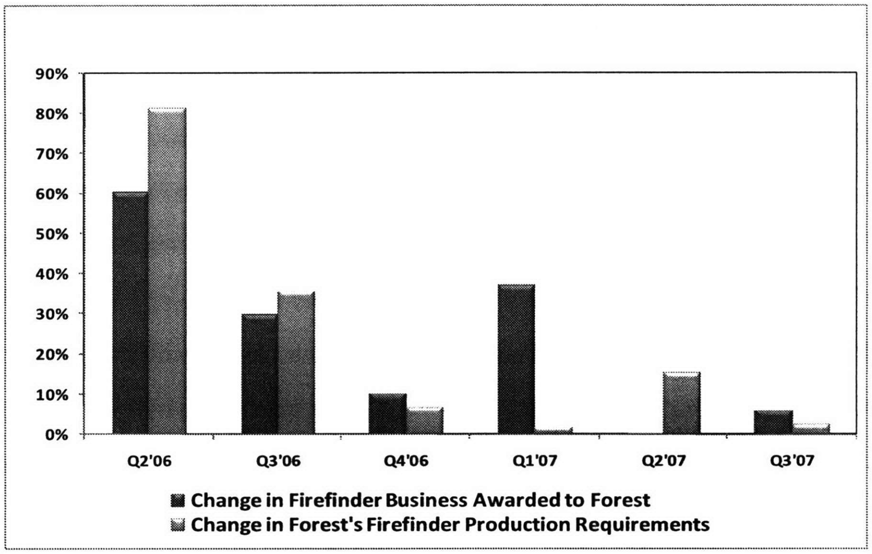


Figure 14: Managing the Bullwhip in the Firefinder Spares Supply Chain

7.4.1. Specific Actions Taken

Forest realized that the PROP enterprise consisted of stakeholders inside and outside of the factory walls. At the highest levels, the objective of managing Firefinder spares demand received excellent support from VPs and Directors in the company. Within the factory, the Firefinder Product Line Manager (PLM) coordinated activities to convert a Demand Plan from NCS to a Capacity Analysis report from Manufacturing. Organizationally, having the PLM drive the process enabled tight alignment on the priorities between Master Planning and Manufacturing. As CCA production capacity constraints surfaced, Manufacturing was able to work them proactively.

Outside of the factory, NCS Program Operations organized efforts involving Forest factory personnel as well as TRS employees to reduce the IOT processing cycle time. TRS decided to use Indefinite Delivery / Indefinite Quantity (IDIQ) contract vehicles to accelerate the Army's procurement cycle times. The IDIQ offered a faster and simpler ordering process for the Army and TRS. By shortening the delay in demand signals from the Army to TRS, the benefit was passed on across the value chain. Mainly, reduction in IOT cycle time incentivized NCS to attempt to smooth out award funding which dampens the order batching effect on supply chain bullwhip.

Moreover, the PLM and the Firefinder Finance Business Manager were included in meetings to turn Program Requirements into a Demand Plan. Because Forest now had better visibility to customers' needs upstream of the supply chain, demand forecast updating became much more accurate over time. Rather than relying on MRP to dictate production schedules, the PLM and Finance Business Manager created a standardized process to evaluate program requirements for Firefinder spares delivery orders. An output of this process was a detailed planning document that became an effective communication medium in PROP working meetings with enterprise stakeholders. Ultimately, PROP gained flexibility as meeting and collaboration frequency evolved from a quarterly basis to more of an event driven basis.

8. Transitioning to the Future PROP

This chapter outlines specific recommendations and their anticipated benefits for Raytheon SAS management. It also flags potential risks to implementing those recommendations in the organization.

8.1. Recommendations

By May 2007, Forest had received over $300M in Firefinder spares awards totaling over 39,000 part orders from NCS. Forest's ability to reduce supply chain bullwhip in the face of exponentially increasing orders demonstrates PROP's potential as an S&OP process for SAS Operations. The actions Forest took in combination with analysis from the seven EA architectural views form the basis of specific recommendations SAS Operations can pursue to enhance PROP.

8.1.1. Strengthen the PROP Working Meeting

The Firefinder spares case study is a great example of a healthy PROP Working Meeting, but this example is the exception and not the norm within SAS Operations. When healthy, the PROP Working Meeting is focused on the global optimum (i.e. execution of the program) rather than the local optimum (i.e. execution of the factory). For the most part, today's PROP Working Meeting is a forum for representatives from SAS Operations' Manufacturing to provide an update on current and future labor and capital constraints, and it rarely includes participation from Program Operations, Supply Chain Management, and Finance. One problem with this structure is by the time Manufacturing reports out its analysis, the data may no longer be entirely accurate. Without cross-functional attendance, the supply chain suffers because of information lags in demand forecast updating.

The real intent of the meeting should be to generate an active discussion across the different functions on how best to allocate manufacturing resources to achieve optimal ROIC for the business. As part of the discussion, each function should feel comfortable asking tough questions such as how Program Operations arrived at its demand plan or why Manufacturing needs additional labor. The benefit of cross-functional attendance and active participation is questions are answered and decisions are made right away. In the past, the representative from Manufacturing did not know the answer to probing questions from the PROP Coordinator, and this resulted in delays in the PROP cycle due to additional follow-up on an issue.

8.1.2. Standardize Processes Where Appropriate

The process architectural view exposed inefficiencies in PROP's lifecycle, infrastructure, and leadership processes. Out of the processes listed, Forecast, MP/Site Simulation, and all of the infrastructure processes would benefit from standardization. Program requirements forecasts are what kick starts PROP. If the information from Program Operations does not meet the expectations of Master Planning, then PROP is delayed and demand forecast updating downstream becomes a problem for SAS Operations' supply chain. To prevent this undesirable result, countermeasures such as standardizing and error-proofing the Forecast process upstream should be implemented. If not centrally coordinated, the MP/Site Simulation process should still be uniform across SAS Operations. This change will benefit factories downstream who are trying to use the process output to manage labor and capital, it will also unlock value for Supply Chain Management and Finance organizations that rely on this data to manage program spends at the SAS level. In addition, key terms like "Program Name" should share the same meaning between all functions in the organization. Lastly, since lifecycle processes rely on healthy infrastructure processes, standardization is critical. If MRP policies are not followed or IOTs take a long time to process, then PROP produces data that is useless to its end customers.

8.1.3. Leverage IT as a Strategic Enabler

Although implementing IT solutions alone cannot solve an organization's problems, certain key processes within PROP clearly stand to gain from SAS Operations' IT transformation. SAS Operations should use the PRISM implementation to revisit PROP's infrastructure processes. Because ERP systems are not very flexible, organizations are forced to standardize business processes. The rigidity of PRISM has driven SAS Operations to examine and streamline how it plans material requirements and manages bills of materials across the organization, and the scrubbed processes should benefit PROP in the long run. Supply chain planning applications are also good tools to relieve the administrative workload for people involved in executing PROP. Currently, PROP relies on dozens of Excel spreadsheets or home-grown databases that are all different in format and function, and most importantly, not easily accessible. Investments in an advanced supply chain planning tool can increase worker productivity, promote knowledge management, and reduce PROP cycle time.

8.1.4. Develop and Proliferate Formal PROP Training

Knowledge transfer of PROP is a clear gap within SAS Operations. If PROP is a priority for SAS Operations, then the organization should invest in training its employees on what PROP is and how it works. One suggestion for disseminating knowledge on PROP is creating a formal training package. The training package should be required for all SAS Operations new hires and easily available for all employees if they would like refresher training.

8.2. Anticipated Benefits for Raytheon Company

The combined recommendations outlined in the previous section can make a positive impact on Raytheon and SAS' bottom line results. In fact, past studies have shown firms that engage in synchronized planning across their supply chain tend to yield significantly higher levels of profitability than those that do not. (Lee and Whang, 2001)

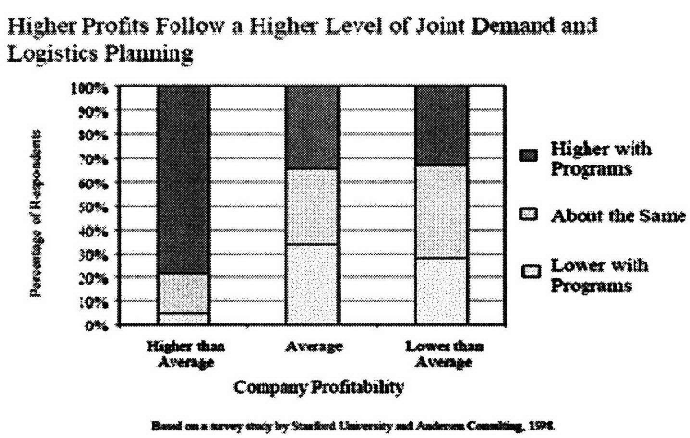


Figure 15: Relationship between Synchronized Planning and Company Profitability

For SAS Operations, the suggested enhancements to PROP enable Raytheon to be fast in its response to changing customer demands. By demonstrating consistency in meeting customer needs, the company builds credibility in an industry where relationships are crucial to securing long term business. Furthermore, in the proposed future state of PROP, cross-functional collaboration is a major theme. With information accessible and transparent across the enterprise, PROP becomes a useful tool to identify and remedy program cost inefficiencies for Raytheon.

8.3. Implementing Change in Organizations

The suggested recommendations to enhance PROP will, undoubtedly, impact SAS Operations at some level. And, simply put, organizational change is not easy. It requires careful analysis to comprehend potential internal resistance and risks to implementation. To help with unpacking these hidden forces, Carroll suggests examining an organization through the three lenses of strategic design, political, and cultural. Each lens is distinctly different from the other, and, when combined, provides new insights and a richer view of the organization. (Carroll, 2002)

8.3.1. The Strategic Design Lens

The strategic design lens views the organization as a machine designed to achieve goals through specific tasks. Designers of the organization set strategy for the firm based on rational analysis of opportunities and capabilities. Sub-sets within the organization are then strategically grouped, related though linking mechanisms, and aligned via certain incentive systems.

The mission of SAS Operations is to be Raytheon's most trusted manufacturer and service provider of space and airborne systems and sensors. To achieve this mission, SAS Operations is designed as a classical matrix organization where Manufacturing supports across all the Program Operations departments. An added level of complexity is that Program Operations Managers are also matrixed into the specific Program Office of the SAS business unit they support. Since Program Operations Managers are incentivized by the performance of their program, Operations Managers are more aligned with their Program

Office team members in another organization than they are with their Manufacturing peers in SAS Operations. This link is further strengthened by the fact that Program Operations Managers are physically located with Program Office team members and not at SAS Operations factories. As a result, the PROP Coordinator must rely on informal linking mechanisms like personal relationships that have developed over time to keep Program Operations Managers engaged in PROP. Where those personal relationships do not exist, engagement with PROP declines.

Although ROIC is measured at the business unit level of the enterprise, tracking factory data back to a particular program and business unit becomes rather difficult for the metric owners. Raytheon SAS' factories are grouped by manufacturing technology capability and geography. Thus, while the manufacturing facilities in California, Texas, and Mississippi can all support the same business unit, they still operate in disconnected silos. At a macro level, all Raytheon SAS employees understand the importance of ROIC. They are aligned to this metric because it is tied to their incentive-based pay. However, the functions of the enterprise are driven by different metrics. Program management and finance care about sales volume, operations cares about units of demand, and supply chain management cares about cost. While all three types of metrics roll into return on invested capital, the connection is not apparent, and because of this, the enterprise functions continue to work at a local rather than a global optimum.

8.3.2. The Political Lens

The political lens views the organization as a struggle for power amongst stakeholders with different goals and interests. Parties with similar goals and interests form coalitions that advocate their positions through impositions or negotiations. How influential each party is in advocating their positions is directly related to how much power they hold in the organization.

To understand who holds power within an organization, one should just "follow the money." At Raytheon, the Program Office wields significant power since they generate revenue for the company. The people in the Program Office are responsible for proposing and winning business. In addition, they authorize release of work to SAS Operations through Contract Authorization Documents and possess valuable information such as a program's Integrated Master Schedule. Obtaining information from the Program Office has required significant coaxing and logical explanation of how data will be used.

With the ongoing PRISM implementation, the power dynamics within SAS Operations have slightly shifted to those stakeholders that are closest to the new enterprise IT architecture. Because the Forest manufacturing facility is the only factory to have gone live with the new system, the rest of SAS' manufacturing network is looking to Forest's factory management team for knowledge transfer and lessons learnt. Developing relationships with those people that understand the strategic IT infrastructure will be beneficial as SAS Operations continues its transition to PRISM.[x]

8.3.3. The Cultural Lens

The cultural lens views the organization as an evolving environment where common reflections and past traditions are passed on from one group to the next. The culture of an organization is driven by how people rationalize situations based on interpretation from their everyday lives. In this sense, organizational culture can be easily impressed upon a new employee in the organization.

Raytheon SAS is a risk adverse organization, and for good reason. Raytheon's hallways contain symbolic reminders that the "war-fighter" depends on the products and services that the company provides. As an engineering company that develops complex technologies for deployment in avionics and space, "mission assurance" is everyone's top priority. Because management decisions can take longer than expected due to a high level of scrutiny, many long-time employees of Raytheon take advantage of established "back doors" to navigate around bureaucratic protocol and accomplish tasks. At times, informal structures, built on relationships and trust over time, are stronger than formal structures built by management.

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[x] California and Texas go-live with PRISM in April 2008 and the SAS Operations implementation will be the subject of a follow-on LFM internship project.

The mergers and acquisitions that led to the creation of Raytheon SAS have left the organization with disparate management systems and processes. On the surface, PROP is faced with synthesizing data from several legacy MRP systems until the ERP implementation is complete across SAS. At a deeper level, the human capital from each of the acquired companies has left Raytheon with various sub-cultures that one needs to be aware of in the SAS landscape.

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9. Conclusion

This chapter summarizes the main points of this thesis and offers Raytheon SAS some ideas for future initiatives to pursue based on observations from the author's research.

9.1. Summary of Key Takeaways

Because PROP is comprised of several connected resources (e.g. people, processes, tools, and metrics), enhancing PROP requires taking a systems approach. This thesis expands on the idea that PROP is an enterprise and uses an EA Framework for identifying opportunities for improvement. Specifically, putting a focus on strengthening the PROP Working Meeting forms the foundation of a recommended PROP future state design that has proven to be successful when implemented to address a challenging supply chain problem for the Firefinder program. In order to sustain a healthy PROP Working Meeting, the organization must embrace strategic initiatives such as IT transformation, knowledge transfer, and process standardization.

9.1.1. Using System Dynamics to Summarize the Impact

A causal loop diagram from system dynamics is a useful tool to illustrate and summarize how these changes to an enterprise PROP will, ultimately, optimize ROIC for the company.

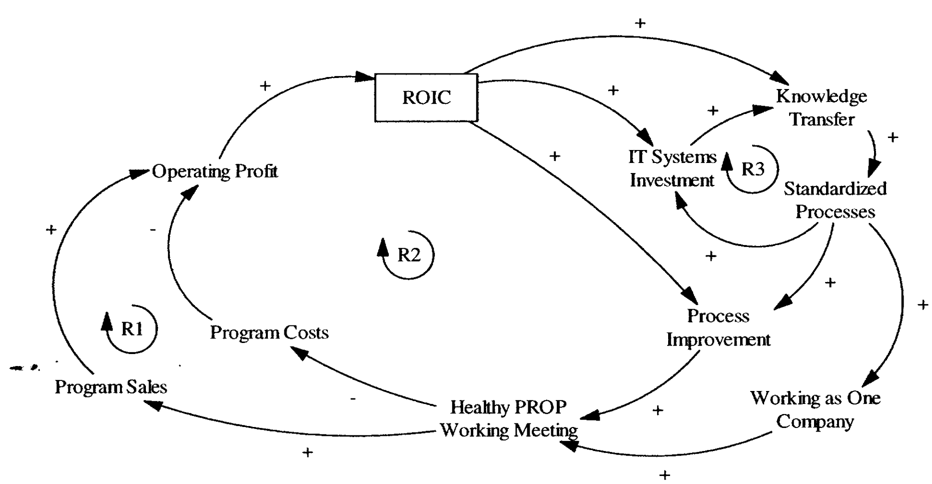

Figure 16: How Recommended Enhancements to PROP Benefit Raytheon

The causal loop diagram contains three reinforcing loops that are of particular interest. In the first loop (R1), a Healthy PROP Working Meeting increases Program Sales by helping demonstrate SAS is operationally competitive in meeting customer demand. In turn, the growth of Program Sales positively impact Operating Profit and ROIC. To close R1, Raytheon can choose to invest its returns on IT, Knowledge Transfer, or Process Improvement, all of which strengthen the Working Meeting through their support of Process Improvement. The second loop (R2) behaves much like the first one except now a Healthy PROP Working Meeting decreases Program Costs which have a negative impact on a firm's Operating Profit. By surfacing inefficient uses of labor, capital, and material early on in a program's lifecycle, the Working Meeting provides timely information for a program execution team to develop successful cost mitigation plans before it becomes too late. As stated earlier, IT, Knowledge Transfer, and Standardized Processes are all extremely vital to sustaining a Healthy PROP Working Meeting. Together, these three critical components form the third reinforcing loop (R3) in the causal loop diagram. Technological advancements in IT (e.g. Internet) promote Knowledge Transfer which breaks down organizational barriers. As a result, the now connected organizations find more opportunities to Standardize Processes between themselves. To close R3, increases in Standardized Processes enable more effective IT systems, a common medium for facilitating communication between connected organizations.

9.2. Future Considerations for Raytheon Company

Although the project was focused on how to enhance PROP for SAS Operations, the time spent researching this topic uncovered other issues for Raytheon SAS to consider. The first issue is related to the PRISM implementation mentioned in this paper. As with most large-scale ERP implementations, the organization will likely experience a "worse before better" period. The faster SAS Operations is able to accelerate the PRISM learning curve over time, the faster it will capture value from its investment in IT. Understanding the strategic drivers that influence acceleration down the learning curve is a great opportunity for future research between SAS and MIT.

Another issue is fostering process sustainability within PROP. To ensure standardized processes are sustained, SAS Operations should consider assigning process owners for those processes. From the process architectural view, PROP as an enterprise contains several critical processes. These processes lack process owners that will provide the dedicated attention needed to support PROP over the long term. Process owners are usually senior managers with end-to-end responsibility for the individual enterprise processes. A subtle, but very key distinction is that process owners are not the same as the people that execute the processes. More importantly, a process owner position is not an interim role in the enterprise, but rather, a permanent position. Hammer stresses this concept for two reasons. First, when business conditions change (as they almost always do), someone needs to ensure that process designs keep up with the evolution of the enterprise. Second, enterprises will revert back to previous undesirable behaviors in the absence of strong process ownership. (Hammer and Stanton, 1999) As Raytheon Company continues its journey towards one company, process owners will become a critical part of SAS Operations to enforce the theme of integration and standardization. Because process owners are a permanent role, management should carefully consider how the organization will support this change.

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