Reducing Enterprise IT Fragmentation through Standard Metrics and Decision Tools: A Case Study in the Aerospace and Defense Industry

by

Benjamin Wheeler

B.S. Industrial & Systems Engineering

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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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Signature of Author ______________________________
May 6, 2011
Engineering Systems Division, MIT Sloan School of Management

Certified by ______________________________
Deborah Nightingale, Thesis Supervisor
Professor of Aeronautics and Astronautics and Engineering Systems Division

Certified by ______________________________
Roy Welsch, Thesis Supervisor
Professor of Statistics and Management Science and Engineering Systems

Accepted by ______________________________
Nancy Leveson, Chair, Engineering Systems Division Education Committee
Professor, Aeronautics and Astronautics and Engineering Systems Division

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

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Abstract

Over the last several decades, manufacturing companies around the world have embraced new and powerful business tools made possible with Information Technology. Major investments are frequently made in enterprise-wide systems, such as Enterprise Resource Planning (ERP) solutions to take advantage of cost saving opportunities. While promising in concept, system implementations can grow to be expensive and complicated during execution, commonly resulting in project de-scoping and sacrifices in functionality and integration. If not carefully managed, this can ultimately lead to an environment of costly custom workaround solutions for years to follow, subverting the central goal of the original investment.

This thesis presents a case study examining Raytheon's initiative to launch an enterprise ERP system (SAP PRISM) in an effort to standardize and modernize supply chain operations. Within the SAP implementation, the repair and retrofit, or depot, business had major integration components de-scoped due to cost constraints. As a result numerous systems have been developed to manage the business, leading to difficulties in process alignment across manufacturing programs.

This work introduces a pilot project with the objective of re-aligning business processes by delivering a portal of common metrics and decision tools to the manufacturing and operations community. With the common portal, the user community gains access to existing centralized data, reducing the need for isolated application development and enabling richer capability.

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

Thesis Supervisor: Roy Welsch
Title: Professor of Statistics and Management Science and Engineering Systems

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1 Introduction

1.1 Overview

Over the last several decades, manufacturing companies around the world have embraced new and powerful business tools made possible with Information Technology (IT). Major investments are frequently made in Material Resource Planning (MRP) and Enterprise Resource Planning (ERP) systems along with Manufacturing Execution Systems (MES) to take advantage of cost saving opportunities.

While these investments can be attractive levers for cost savings, project complexity and change management challenges are frequently underestimated during project planning. Implementations can grow to be expensive and painful during execution, commonly resulting in project de-scoping and sacrifices in functionality and integration. If not carefully managed, this can ultimately lead to an environment of system workarounds, custom solutions and peripheral application development for years to follow. Ironically, this implies that a system intended to serve as a standardized transactional backbone has the potential to proliferate into a web of non-standard business processes. When a firm falls into this post-implementation trap it is common to focus development efforts on customized solutions and add-on applications rather than taking an approach centered on standardization and process alignment.

This thesis explores the United States defense industry in the pre- and post-Cold War eras, and the business environment that prompted large scale IT investments. Some frameworks from the literature for evaluating enterprise IT systems are reviewed and a case study is presented reviewing the motivation and history behind a large scale ERP system implementation across multiple business units within Raytheon. A deeper look will be taken to examine the decision to delay the design elements within the repair and retrofit (depot) business process. These processes were historically managed outside the MRP environment and required process re-engineering emphasis prior to automation strategies. The current state of depot business processes are surveyed and a methodology is proposed to prioritize future IT projects considering business process alignment in conjunction with traditional criteria. Finally, a proof of concept project that was designed to promote business process alignment is presented, demonstrating results of improved management capability, process streamlining and labor reduction.

1.2 Organization of Thesis

This thesis is organized into eight chapters as described below:

Chapter 1 – Introduction: General information on thesis content and structure.

Chapter 2 – Lean Manufacturing and IT in the Defense Industry: This chapter briefly describes the pre- and post- Cold War conditions within the United States defense industry, and touches on some of the motivations for the shift toward lean manufacturing and investment in IT infrastructure.

Chapter 3 – Raytheon and Business Unit Overview: An overview of Raytheon and its business units is presented along with a general description of production contract manufacturing activity versus depot activity. Additionally, aspects of Raytheon's organizational dynamics which influence business operations are discussed.

Chapter 4 – Literature Review: Prior research is presented which covers some frameworks for evaluating enterprise IT systems in the context of Raytheon's IT architecture strategy. Common large scale industrial IT implementations are also reviewed.

Chapter 5 – SAP/PRISM History at Raytheon: The events that lead to Raytheon's decision to invest in an enterprise ERP system are reviewed along with the decisions that were made to postpone key components of the depot ERP solution.

Chapter 6 – Depot Project Review: This chapter describes the proof of concept project that was carried out as part of the research in an investigation of application development aimed at business process alignment. As part of the research, a broad set of facilities were surveyed in order to set a baseline for comparison across business units and programs. From this baseline assessment, the scoping of the project, project selection and project process are explained in detail.

Chapter 7 – Conclusions and Recommendations: Summarizes the thesis and contains recommendations for future projects at Raytheon and recommendations for future research.

2 Lean Manufacturing and IT in the Defense Industry

Over the last half century the defense industry has undergone a massive transformation in response to the shifting demands of national security and increased competition for government contracts. At the core of this transformation is the need for individual firms to operate with agility and cost competitiveness. These post-cold war market forces led Raytheon, like many other defense contractors, down the path of lean manufacturing and the implementation of productivity enhancing IT systems. This chapter will explore the historical context of lean manufacturing in the pre- and post-Cold War defense industry.

2.1 The Defense Industry Pre- and Post-Cold War

During the Cold War of 1970's through early 1990's, the United States was engaged in a race for military dominance with the world's other superpower, the Soviet Union. This period of massive expansion was characterized by a focus on performance and capability with very little concern for cost and speed. Government contracts during the cold war were typically structured in such a way that all costs for product research and development and manufacturing were guaranteed to be reimbursed by the government and the contractor would receive a predetermined premium upon contract fulfillment, either piecewise or in full. This type of arrangement, known as a "cost-plus" contract, was useful to incentivize contract bids for large scale technology projects of the time because it significantly reduced risk of investing in large up-front capital costs for the bidding firms. However, while this contract structure incentivized heavy investment in defense technology it also meant that firms had little or no incentive to reduce costs and improve productivity as their expenditures were more or less guaranteed to be reimbursed.[1] As a result of the cold war build up and exploding contract costs, National Defense

[1] Deutch, John, Consolidation of the U.S. Defense Industrial Base, Acquisition Review Quarterly, Fall 2001.

spending increased by 32% as a percentage of GDP and 162% nominally from 1978 to near its cold war peak in 1986.[2] (Figure 1)

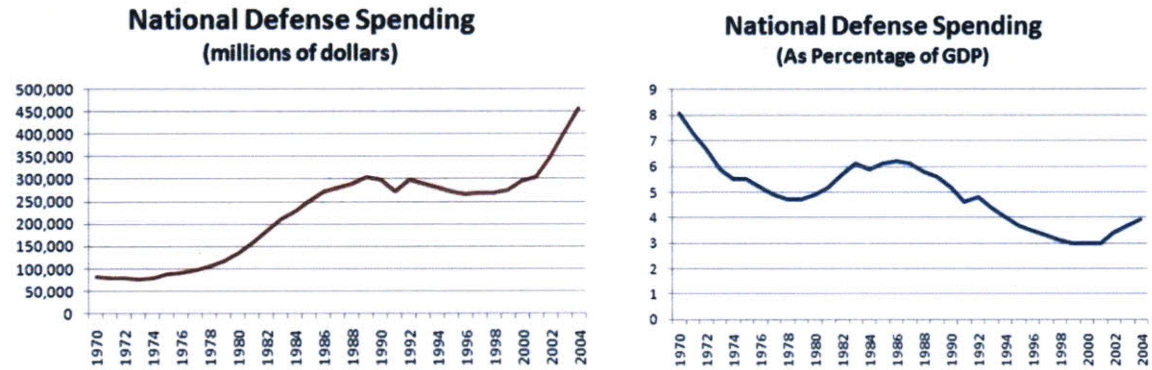

Figure 1: National Defense Spending 1970-2004[2]

After the collapse of Soviet Union in 1991 the national priority for rapid military expansion dissipated and the bloated defense industry was facing an uncertain future. The US Congress was set to make drastic cutbacks in defense spending and the federal government was looking at ways to make the defense industry more efficient. Perhaps the most disruptive idea for transformation was to promote a policy of industry consolidation.

In 1993, Secretary of Defense Les Aspin ordered a "bottom-up review" of U.S. defense companies that concluded that the industry was in need of massive restructuring in order to reduce the defense asset base. Then Deputy Secretary of Defense William J. Perry announced to industry leaders, at what has come to be referred to as the "Last Supper," Department of Defense (DoD) policy to encourage consolidation.[3] As predicted, over the next five years federal defense spending subsided to pre-Cold War levels dropping 22% as a percentage of GDP and 8% nominally[4] (Figure 1). During this time period large contractors like General Dynamics, Texas Instruments and Ford Aerospace sold some or all of their defense interests as a

[2] Budget of the United States Government, Fiscal Year 2006, Historical Tables.
[3] Deutch, John, Consolidation of the U.S. Defense Industrial Base, Acquisition Review Quarterly, Fall 2001.
[4] Budget of the United States Government, Fiscal Year 2006, Historical Tables.

few large companies like Raytheon, Boeing and Northrop began to pull them into their portfolios. The frenzy of mergers and acquisitions continued until 1998, when the Department of Defense unexpectedly reversed the pro-consolidation policy and urged the Department of Justice to reject the proposed merger of Lockheed Martin and Northrop and the proposed General Dynamics acquisition of Newport News Shipbuilding. The agencies had become concerned that the consolidation had begun to overreach its intended result and that a further reduction in prime contractors would limit competition. Furthermore, the asset base reduction that was expected following the consolidation activity had failed to materialize.[5]

As the industry was reaching what was viewed as equilibrium between efficient asset utilization and fair market competition in the early 2000's, tragedy struck in the form of the September 11, 2001 terrorist attacks. Defense spending once again began to rise but the scenario was a much different one than during the Cold War. Wasteful government spending was being looked at with increasing scrutiny and cost cutting initiatives were now a fact of life in the defense world.

2.2 Lean Manufacturing in the Defense Industry

Just as the Department of Defense looked to promote industry consolidation in the early nineties for overall market health and sustainability, defense companies themselves began to look at ways improve performance while lowering costs. For an example, they had to look no further than the state of the U.S. automotive manufacturing base. The value of adopting lean manufacturing was becoming apparent as the "big three" were scrambling to compete with Asian automakers that had implemented lean manufacturing and the "Toyota Production System". As a response, the presidents of 29 aerospace companies along with the U.S. Air Force agreed in 1993 to form a consortium sponsoring the research of lean principles as they applied to the defense industry. The Lean Aerospace Initiative is a joint partnership between MIT

[5] Deutch, John, Consolidation of the U.S. Defense Industrial Base, Acquisition Review Quarterly, Fall 2001.

and industry aimed at facilitating the focused and accelerated transformation of industry stakeholders into lean enterprises.[6]

2.3 Information Technology in the Defense Industry

A case could be made that military spending and technology innovation have been inextricably intertwined over the last 70 years. Beginning in World War II, the production of various weapon systems and the building of a massive manufacturing infrastructure quickly solidified the government's expanded role in leading edge technology development. Decades of advancement in space flight, telecommunications and countless other fields have their roots in government backed defense projects. Information technology and the dawn of the internet can also be traced backed to defense related projects. In 1996, MIT researcher Lawrence G. Roberts approached the Defense Applied Research Projects Agency (DARPA[7]) to develop a new computer network concept and put together his plan for the "ARPANET", publishing it in 1967.[8] Over the next several decades ARPANET would evolve as a joint project between academia and the government to become the internet as we know it today. Interestingly, the explosion in IT systems and productivity applications in the 1980's and 1990's was occurring just as the industry was beginning to look for solutions that would yield productivity gains. However, as this was also a period of industry consolidation, many challenges faced in integrating the IT systems of feverishly merging companies.

[6] MIT Lean Advancement Initiative. 2011. *LAI Overview*. Retrieved from http://lean.mit.edu

[7] The Advanced Research Projects Agency (ARPA) changed itsname to Defense Advanced Research Projects Agency (DARPA) in 1971, then back to ARPA in 1993, and back to DARPA in 1996. We refer throughout to DARPA, the current name.

[8] Leiner, Barry M., A Brief History of the Internet, ACM SIGCOMM Computer Communication Review, Volume 39, Number 5, October 2009.

3 Raytheon and Business Unit Overview

While the previous chapter provides a useful backdrop of the dynamics playing out in the defense industry throughout the past half century, Raytheon has its own history with important details that influence the company as it is today. This chapter outlines the organizational and cultural environment of Raytheon and the business units that this research was conducted in.

3.1 Company History and Business Units

Throughout its 88 year history, Raytheon has undergone many changes that have shaped the company into what it is today. A storyline of diverse technology developments, classified programs, and assorted company mergers and acquisitions have had a lasting impact on company operations, political structure and culture.

Founded in Cambridge, MA on what is today the MIT campus, Raytheon began as a manufacturer of radio tubes when the technology was in its infancy. The company experienced a major growth period during World War II, when its support for the war effort with military radar systems gave the U.S. a technological edge over the axis powers. In the post-war economy, Raytheon adapted World War II radar technology to invent microwave cooking and developed the first guided missile, solidified itself as a global technology leader with a pioneering tradition.[9]

Raytheon is divided into six business units today, each focused on a unique portfolio of technology-driven products and services. Each business unit is headquartered in a different location, while the

[9] Raytheon Company. 2011. *Raytheon: A History of Global Technology Leadership*. Retrieved from http://www.raytheon.com/ourcompany/history/

corporate headquarters has its own site in Waltham, MA close to its original Cambridge location. The following are short descriptions of each business unit and their function.[10]

- Raytheon Space and Airborne Systems (SAS), where the majority of this research was conducted, is headquartered in El Segundo, CA with 11,700 employees and 2010 revenues of $4.8 billion. SAS is a leading provider of sensor systems including Active electronically scanned array (AESA) radars and Electro-optic/infrared (EO/IR) sensors.

- Raytheon Integrated Defense Systems (IDS) delivers integrated air and missile defense, radar solutions and naval combat and ship electronic systems. In 2010 it had revenue of $5.5 billion with over 14,000 employees.

- Raytheon Intelligence and Information Systems (IIS) serves the U.S. and allied defense agencies to integrate information systems to better manage their data and develop custom solutions. In 2010 IIS had revenue of $2.8 billion with 8,400 employees.

- Raytheon Missile Systems (RMS) designs, develops, and produces missile systems for U.S. and allied forces, including air-to-air, strike, naval weapon systems, land combat missiles, guided projectiles, exoatmospheric kill vehicles, and directed energy weapons. In 2010 IIS had revenue of $5.7 billion with 12,400 employees.

- Raytheon Network Centric Systems (NCS) develops and produces mission solutions for networking, command and control, battlespace awareness, and air traffic management. In 2010 NCS had $4.9 billion in revenue with 13,750 employees.

[10] Raytheon Company. 2011. *Raytheon Company: Businesses*. Retrieved from http://www.raytheon.com/businesses/

- Raytheon Technical Services Company (RTSC) supports government and commercial customers with training, logistics and engineering solutions at 440 sites across 80 countries. In 2010 RTSC had $3.2 billion in revenue with 10,000 employees.

3.2 One Raytheon

Over the last several decades, Raytheon has pursued expansion through acquisition, growing to a 75,000 employee company with revenues of over $25 billion in 2010. Many of the major acquisitions came during the industry consolidation period of the mid 1990's. Understandably, this rapid expansion made it a challenge to keep the organization united. In response, the company launched the "One Raytheon" or "OneRTN" campaign as an important reminder that Raytheon's success is a dependent on leveraging best practices across the enterprise and ensuring a unified customer experience. Before becoming CEO, then president Bill Swanson clearly articulated this vision in a memo to Raytheon employees:

> *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.*[11]

This sentiment is echoed still today, as one of four key points in Raytheon's corporate strategy reads: "Continue to be a Customer Focused company based on performance, relationships and solutions"[12].

[11] Swanson, Bill. July 18, 2003. *Excerpt from memo to employees.*
[12] Raytheon Company. 2011. *Raytheon Company: Raytheon's Vision, Strategy, Goals and Values.* Retrieved from http://www.raytheon.com/ourcompany/ourculture/vsgv/index.html

3.3 Production versus Depot Contracts

Given Raytheon's product portfolio, the business landscape is dominated by government contracts with varying levels of open and classified projects. These contracts can differ greatly in structure depending on whether the customer is within the U.S. or a foreign government or may even depend on which arm of the military it services. Across all six business units, customer contracts and manufacturing activities are typically classified into two broad categories (in addition to research and development): production contract manufacturing and customer returned material serviced internally, known as "depot" contracts.

Production manufacturing contracts make up the largest percentage of Raytheon's business. These contracts are typically larger volume programs that are paid for either upon unit delivery, contract fulfillment or by set contract milestones. Depot activities make up a smaller but growing segment of the business and can be classified into three major categories:

1) ***Retrofits and Upgrades*** – Planned customer returns where Raytheon is contracted to retrofit or upgrade a unit being sent back from the field. This type of activity is generally very similar to production operationally with defined product routings and bill of material lists.
2) ***Warranties*** – Warranty events are usually either pre-emptive repair actions in response to well known failure modes or high frequency, simple replacements.
3) ***Break/Fix*** – Unplanned product failures requiring disposition and diagnostic testing. Due to potentially high repair costs, customer authorization is often required to proceed after inspection.

With the U.S. military as its primary customer, the revenue of Raytheon is heavily dependent on the level of U.S. Department of Defense spending. Traditionally, during times of peace the company has seen declining growth while in periods of military buildup, it has prospered. During the post September 11 anti-terrorism campaigns in Iraq and Afghanistan, for example, an explosion in demand for unmanned aerial vehicles and surveillance equipment translated into very high profits. However in the coming years when funding for new hardware is expected to decline, spending on maintenance and lifecycle improvement are projected to rise. Today, Raytheon supports more than 600 depot contracts in SAS alone. This number is expected to increase as Raytheon continues to support its fielded systems domestically and internationally. It is important to note that depot activity can occur within the walls of Raytheon facilities or remotely in the field by engineers and technicians.

3.4 Organizational and Cultural Landscape: Three Lens Analysis

In any organization, there are multiple dimensions to consider when evaluating a change effort. This chapter uses the three lens framework as described by MIT professor John Carroll[13] to describe the landscape around which this research project was conducted. Under Professor Carroll's framework, an organization can be viewed though three lenses: the strategic lens, the political lens and the cultural lens. The strategic lens looks at how human, physical and information resources are organized within an organization. The political lens focuses on the influence of individuals and groups within an organization to control how decisions are made. The cultural lens looks at how the history, attitudes and beliefs affect the decisions that are made.

3.4.1 Strategic Design Lens

Having grown inorganically in a relatively short period of time Raytheon was faced with the challenge of integrating a diverse set of management structures into a single cohesive division. Solutions for the depot environment must consider a variety of diverse internal and external users and customers. Flexibility and agility of duties and assigned systems roles must be part of the system design.

[13] Carroll, John, Introduction to Organizational Analysis: the Three Lenses, MIT Sloan School, August 2001.

3.4.2 Political Lens

Raytheon is organized in a matrix environment and as such must continuously balance the specific programmatic needs of its customers with optimized efficiency and consistency across its functions. This structure while agile and powerful creates challenges when designing common processes. The organization is largely divided by product family, some of which are classified projects, which has reinforced a strict and very limited linear chain of command. As the products and operations of Raytheon are technically complex, there is also an underlying knowledge-based power structure where individuals with high levels of experience or technical expertise carry tremendous weight even in important strategic functional decisions.

3.4.3 Cultural Lens

Raytheon has a varied set of strong cultural norms and also subtle nuances woven into the organizational fabric. As is typical with many companies in the Aerospace and Defense industries, the workforce demographic is skewed toward engineers and ex-military personnel, including within the leadership team. Presumably because of the veteran presence in the workforce and because of the criticality of Raytheon products in military operations, patriotism serves as a strong motivator throughout the organization. Although these attributes would seem to imply organizational alignment toward a common goal, there are new challenges that exist in a consolidated industry environment: 1) legacy company experiences, 2) business unit specialization and 3) geographic differences.

3.4.3.1 Legacy Company Experiences

With Raytheon's many acquisitions over the years, different company processes and experiences were meshed into the same organization. Creating common processes in these environments is a challenge as different is not wrong, it just creates variability. Someone has to change to eliminate non value-added variability and change is uncomfortable and generates initial resistance. Identification with former legacy company processes is a hurdle that must be faced as processes move towards a new company standard.

3.4.3.2 Business Unit Specialization

Raytheon is divided into six business units, each focused on a separate application of technology. With this separation, each unit has developed a slightly different customer set and product profile. For example, some products are high volume, some generate a single product every 15 months, some have multiple levels of indenture to manage and some are integration only products. However, because of the close relationship between products, processes and services they frequently work together on projects.

3.4.3.3 Geographic Differences

Although Raytheon is headquartered near Boston, MA a large portion of its operations are spread throughout the Southern and Southwestern US. Many of these sites have developed different operating models based on regional differences. For example some states are union-oriented and have more expensive labor (such as California and Massachusetts) and some are non-union with less expensive labor (such as Mississippi and Florida). These factors have driven a shift in manufacturing volumes toward the southeast where it is more feasible to optimize affordability for Raytheon customers.

4 Literature Review

While the benefits of enterprise IT systems are understood, the execution of large scale IT investments is an incredible challenge for any company to take on. However this barrier is also the reason why companies that can do it well enjoy a competitive advantage over those who struggle. Over the last several decades there has been a vast amount of research examining the role of IT in large enterprises. This section presents some useful frameworks for evaluating the role of IT within an organization and to what extent value can be extracted from IT architectures at different levels of maturity.

4.1 Information Technology Operating Models

A 2005 paper published by the MIT Center for Information Systems Research (CISR)[14] introduces a framework whereby a firm can proactively align its high level corporate IT strategy with the corporate business strategy. The paper describes two dimensions by which the IT strategy should be considered. In the first dimension, a firm must decide on the level of standardization across operational units (business units, market segments, regions, etc.) Second, a firm should decide on the level of business process integration across the units. Based on the decisions for the two dimensions a firm can settle into one of four operating models (Figure 2).

The operating model should serve as a guide for how information systems are to be used to carry out the corporate business goals. The four quadrants are generally described by the following summaries:

> ***Diversification*** (low standardization, low integration) is preferable for an organization interested in a decentralized design where different business units or regions operate with local autonomy. A good example of this would be a consumer goods company, such as Johnson & Johnson, whose strategy is to maintain brand autonomy.

[14] Ross, Jeanne W., Forget Strategy: Focus IT on Your Operating Model, CISR Research Briefing, Vol. V, No. 3C, December 2005.

Unification (high standardization, high integration) is a model adopted by a company that values reliability, predictability and a standard customer interface. An example of a company with a unified model would be an airline.

Coordination (low standardization, high integration) models focus on system integration between organizational units. An example of coordination may be a network of car dealerships/service centers in a particular region that have independent businesses but share a common IT infrastructure for inventory and communication.

Replication (high standardization, low integration) models focus on standardization of business processes and customer experiences but have a low level of integration between units. An example of this type of model would be a fast food franchise, where the systems at each location are virtually identical but there is almost no interface between stores.

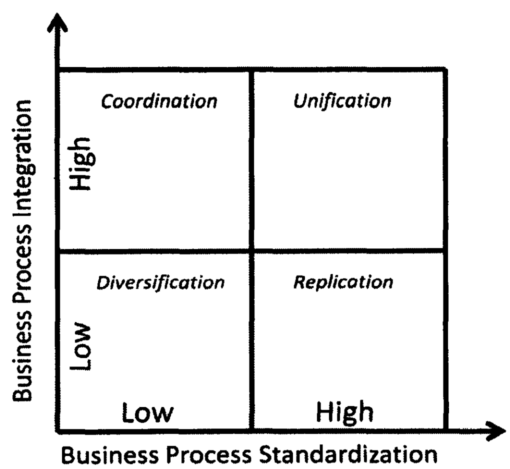

Figure 2: Graphical representation of the four operating models[15]

[15] Ross, Jeanne W., Forget Strategy: Focus IT on Your Operating Model, CISR Research Briefing, Vol. V, No. 3C, December 2005.h

While the operating model concept is a useful tool at a high level, it can be difficult to clearly identify with one model when considering multiple levels within an organization. For example a multinational automotive company may operate in a diversified model at the global level, but in a coordinated or unified model within a region.

The enterprise level strategy of the Raytheon operations group studied in this research is to drive toward a common set of support tools with a highly integrated back end across all business units in order to meet varying needs for the customer base. This is in line with the corporate directive to drive toward the vision of "One Raytheon", where waste and duplication is eliminated and natural synergies are leveraged. Within the framework proposed by CISR, this strategy fits within "Coordinated" operating model.

4.2 Phases of Information Technology Maturity

In most traditional organizations, it is assumed that the role of technology strategy is to follow and enable the strategic objectives of the business strategy. However, as information technology continues to evolve, more firms are adopting strategies that are centered on developing innovative capabilities enabled by their IT architecture. This maturation of IT and business strategy alignment was the basis of a study published in 2003 by Ross, presenting a framework of four distinct stages of increasing IT architecture competency (Figure 3). Using a sample of 40 case studies, the research identified the following phases[16]:

1) ***Application silo architecture*** – An architecture that consists of a collection of individual specialized applications rather than an enterprise-wide cohesive framework. In this stage IT buys or develops applications to address specific functions with efforts focused on local optimization.

[16] Ross, Jeanne W., Creating a Strategic IT Architecture Competency: Learning in Stages, CISR Working Paper 335, April 2003.

There is typically little or no constraints regarding organizational standards, however this freedom becomes offset by the difficulty in linking disjointed systems.

2) ***Standard technology architecture*** – An organization-wide framework that provides efficiency gains through technology standardization or centralization. An organization in this stage is frequently focused on reducing the number of platforms to reduce complexity, cut costs and begin integration of individual applications.

3) ***Rationalized data architecture*** – A more organized architecture that expands to standardize system level data and supporting business processes. In this stage companies shift resources from application development and into infrastructure development. Central data warehouses are often implemented in an attempt to make application information more accessible and there is a movement toward process standardization and optimization.

4) ***Modular architecture*** – An architecture that builds on global standards to enable new capabilities and local customization without compromising the integrity of the infrastructure standards. An organization in this stage can ensure predictability of core processes and data integrity and is utilizing its infrastructure to generate new and innovative customer solutions.

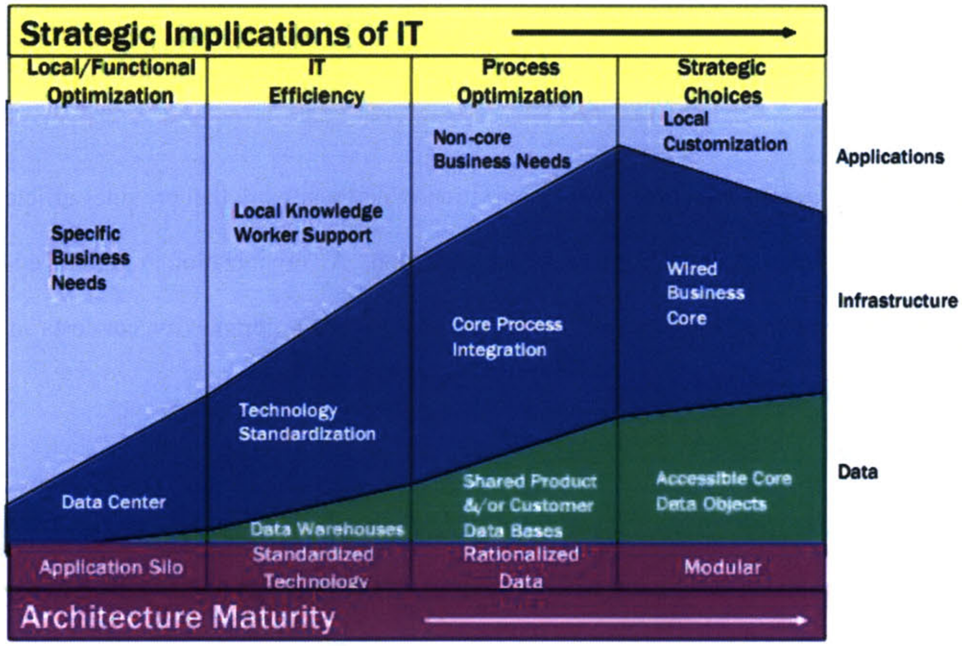

Figure 3: Graphical representation of the four stages of architectural maturity[17]

4.3 Common Large Scale Industrial IT Implementations

Since the early 1970's, large enterprises have been turning to IT solutions to manage complex management activities. Complex tasks once performed manually requiring very high levels of coordination can be now be performed in seconds using specialized computers and software. While the trend began with simple shop floor control systems and MRP systems for inventory management, the ERP systems of today serve as information backbones linking virtually dozens of enterprise functions like supply chain, financial accounting, payroll and production control. This section provides an overview of functionality for the most common large-scale IT investments.

[17] Ross, Jeanne W., Creating a Strategic IT Architecture Competency: Learning in Stages, CISR Working Paper 335, April 2003.

4.3.1 Overview of MES Systems

In the 1970's and 1980's manufacturing companies first began using early computer system to collect data and store product information and manage factory floor operations. Many home grown systems were created independently with increasing functionality eventually until standards were developed in the 1990's and early 2000's in order to promote interface capability and interoperability. Today most MES systems follow ANSI/ISA-95 standards and have the ability to manage material specifications and product flow, manage process scheduling, collect manufacturing data and communicate directly with machinery.[18]

4.3.2 Overview of MRP and ERP Systems

Prior to the advent of modern computing technology, inventory control and management operations were largely performed by hand or later on with rudimentary tape storage drives and punch card machines. Even with machine assistance the process was tedious and prone to errors. Early computers were incapable of square root calculations, meaning that Economic Order Quantity (EOQ) calculations had to be hand calculated in intermediate steps and re-entered into the machine. Furthermore, tape backups and similar technologies only allowed for one-dimensional data storage, whereas Bill of Material (BOM) explosions and time phases calculations required multi-dimensional computing meaning that many intermediate steps were required for more advanced functions. When Random Access Memory (RAM) and Integrated Circuit (IC) technologies were developed a whole new era of capability became possible.[19]

The first widely acknowledged MRP system was developed in the late 1960's as a joint development between the tractor manufacturer J.J. Case and IBM. The system, and other early MRP systems like it, featured integrated demand forecasting, master scheduling, procurement and limited shop floor tracking capability. Throughout the 1970's and 1980's, advancements in hardware capability enabled more

[18] ISA, European Office. 2010. *ISA-95 Enterprise Control Systems*. Retrieved from http://www.isa-95.com/subpages/technology/isa-95/isa-95.php

[19] Jacobs, F.R. and Weston, F.C. Jr (2007), "Enterprise resource planning (ERP) – a brief history", Journal of Operations Management, Vol. 25 No. 2, pp. 357-63.

complex software to be developed, covering more aspects of business operations. During this time, companies like IBM, SAP (Systemanalyse und Programmentwicklung), Oracle and J.D. Edwards came to dominate the business software market, developing new features and integrating new functionality into their suites.[20]

With the level of functionality having increased greatly from the first MRP implementations to now include financial accounting, invoicing and shipping information and transactional histories, a new term was needed to differentiate the new, more advanced systems from their predecessors. In 1990 the term Enterprise Resource Planning (ERP) was coined in a report published by the Gartner Group to describe the newer systems.[21] Throughout the 1990's as concern grew within industry over potential problems associated with Y2K compliance of current systems, investment in new state-of-the-art ERP systems increased dramatically. Today the ERP market continues to grow and is a significant source of innovation and operational improvement in virtually all modern industries. According to a 2007 study by AMR Research, Inc., ERP application revenues are expected to reach $47 billion by 2011.[22] Although there are many general and customized competitive ERP products available, SAP and Oracle dominate the market with an estimated market share of 31% and 25%, respectively.[23]

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[20] Jacobs, F.R. and Weston, F.C. Jr (2007), "Enterprise resource planning (ERP) – a brief history", Journal of Operations Management, Vol. 25 No. 2, pp. 357-63.
[21] Wylie, L. (1990). ERP: A vision of the next-generation MRP II, Computer Integrated Manufacturing, Gartner Group S-300(339.2): 1–2
[22] Jacobson, S., Shepherd, J., D'Aquila, M., and Carter, K. 2007. "The ERP Market Sizing Report, 2006–2011," AMR Research, Boston, MA
[23] Panorama Consulting Group. 2011. *ERP REPORT.* http://panorama-consulting.com/resource-center/2010-erp-vendor-analysis/.

5 SAP/PRISM History at Raytheon

Raytheon's ERP undertaking began more than fifteen years ago when representatives from the SAS and NCS business units started exploring new ways to leverage information systems to gain operating efficiencies. Although separate business units experimented locally with ERP deployments, it was not until 2004 that a formal enterprise decision to implement SAP was announced.[24] The project would serve as a demonstration of the corporate office's commitment to the "One Raytheon" vision. This section describes the historic timeline of key events (Figure 4) and activities leading up to full SAP deployment including the decision to de-scope depot operations functionality.

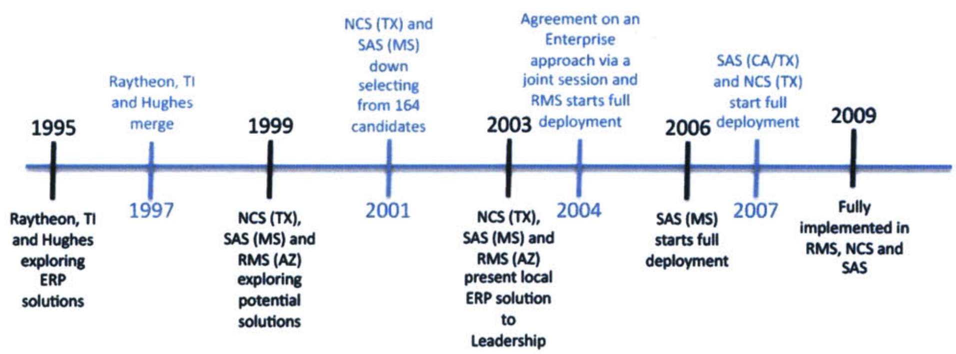

Figure 4: Timeline of Raytheon ERP Implementation (Chun, 2010)

5.1 Early ERP Investigation

In the mid-1990's, ERP systems were coming to the forefront in manufacturing operations. Raytheon, Texas Instruments and Hughes Aircraft (separate companies at the time, would later all become Raytheon via acquisition) all investigated the business case for ERP deployment before ultimately deeming full-scale implementations to be too risky at the time. However, none of the companies completely abandoned the effort, realizing how critical successful ERP integration would become in the defense industry.

[24] Chun, Julie, "Using a Design for Project Implementation (DFPI) Methodology to Accelerate Return on Investment (ROI) of an Enterprise Resource Planning (ERP) System," MIT LFM Thesis, June 2010.

Hughes investigated a software solution from Manugistics (acquired by JDA in July, 2006[25]), but ultimately decided to against the investment. Texas Instruments went on to install a partial ERP system that integrated with their factory MES system to automate basic material tracking functions. By 2001, different groups within Raytheon SAS, NCA and RMS divisions were all independently re-exploring commercial ERP solutions. While SAS and NCS had joined efforts to investigate potential offerings in house, RMS had contracted the Gartner Group to help conduct the study. SAS and NCS eventually narrowed their search to the small defense-oriented ERP company, Cubicorp, in 2003 as they felt it best fit their unique needs. Around the same time, based on their needs and the recommendation from Gartner Group, RMS went forward with an SAP proof of concept pilot system.

However their plans were not well received by the executive management team, who were looking for a global solution that could be used to serve all of Raytheon's business units. In response, the teams came together in January of 2004 and settled upon a Raytheon-wide ERP strategy based around extending the RMS SAP pilot into an enterprise ERP backbone.[26]

5.2 PRISM Implementation

Under the guidance of Raytheon's leadership team, a dedicated team comprised of representatives across different business units and consultants developed a customized instance of SAP's ERP product called PRISM. A large portion of the initiative was dedicated to developing a tightly integrated interface between PRISM and the existing MES (Visiprise VM) for production contract manufacturing. Other important infrastructure interfaces were included in the design, to such systems as SAPTrack, a materiel

[25] JDA Software Group. 2010. *Manugistics Acquisition.* Retrieved from http://www.jda.com/company/manugistics-acquisition/

[26] Chun, Julie, "Using a Design for Project Implementation (DFPI) Methodology to Accelerate Return on Investment (ROI) of an Enterprise Resource Planning (ERP) System," MIT LFM Thesis, June 2010.

move request and tracking system, SAP MII, a manufacturing control system, and SAP APEX, SAP's financial module.

To minimize risk associated with business disruption a phased approach to implementation was followed. The first full implementation was completed at RMS by mid-2006, followed by a second installation in SAS's Mississippi facility in early 2007. A larger implementation, considered the major PRISM "go-live" event, for the SAS and NCS sites in California and Texas was completed in January 2009. At the time of this writing, implementation efforts were underway in Raytheon's IDS division with plans to roll out PRISM across five of the six business units in most facilities with significant manufacturing activity.

5.2.1 PRISM Transformation: Evaluating the Maturity Level of IT Competency

When considering Raytheon's ERP journey, the "Phases of IT Maturity" framework proposed by Ross (section 4.2) is a useful way to evaluate the state of their IT architecture. Prior to the PRISM implementation the operations groups within SAS, NCS and RMS were functioning primarily within a structure of application silos designed specifically for a unique use case. At that time many sites and programs developed custom spreadsheet tools, databases or partial ERP systems to modernize their value chain.

The ambitious PRISM initiative was designed to simultaneously implement a standard technology architecture and move through to a rationalized data architecture. The strategic decision was to heavily invest in a revolutionary new architecture, rather than to take a more evolutionary approach. For more than a full year, the design and implementation phase of the massive initiative was staffed by a team of over 100 dedicated employees and consultants with a very heavy price tag for the investment. This was an enormous undertaking and although the PRISM team had a careful change management plan, the implementation had mixed results. In this vein, the architectural maturity level of the transformation can be viewed as a tale of two business areas.

5.2.2 PRISM Implementation for Production

The primary focus of the PRISM team was to ensure a fully integrated ERP solution to support production contracts, a reasonable goal as production contracts make up a large percentage of overall revenue and are much simpler to manage logistically than depot. By all accounts, the system "go-live" for production was considered a monumental success and pivotal moment for Raytheon. The transition of core inventory management processes to PRISM occurred with no significant disruption to the business. According to the management team:

- There were no missed or delayed deliveries as a result of implementation
- There were no halted production activities due to delayed inventory deliveries as a result of implementation
- There were no missed or delayed supply chain payments as a result of implementation
- There were no disruptions to payroll as a result of implementation

Since the "go-live", much progress has been made in developing a Business Intelligence (BI) platform for production, leveraging the centralized architecture to create business value. Based on these successful accounts it is safe to say that the beginning stages of a rationalized data architecture has been reached for production.

5.2.3 PRISM Implementation for Depot

While the PRISM implementation was heralded as a major success for production contract manufacturing, support for depot operations proved to be a deeper challenge. Although depot was included in the PRISM deployment, the PRISM-VM integration for depot activity was intentionally removed from the project scope due to its complexity, with the intention of completion within the scope of a future project. Because of this disconnect between shop floor and inventory management systems, centralized data is difficult to access and little progress has been made to turn this data into meaningful information for depot managers. Because depot activities have largely continued to exist outside the formal integrated ERP system, business units and constituent programs have developed independent solutions for how to manage their depot activity. Various approaches have been developed to track activities and material flow and to ease the workload requirements of day-to-day business decisions. The depot process set, as previously discussed, is ripe for process re-engineering to bring it up to the level of the integrated production ERP environment. Opportunities for improvement include:

- Streamlining maintenance of records requiring duplicate data entry
- Optimization of IT investments through common solutions, positively impacting hardware, maintenance and development efforts
- Enhancing efficiency through automation of manual processes

In the context of the "Architectural Maturity" model, depot presents an interesting case. The PRISM initiative successfully moved the organization away from existing custom applications and established standard platforms. However because these standard platforms have not yet been integrated for depot operations, they cannot be used as a seamless ERP backbone. For many business processes, information must be retrieved or entered into multiple systems, often in a manual fashion or by using available workarounds. Ironically, these system workarounds have effectively enabled the use of custom applications developed by individual depot programs throughout Raytheon in an effort to perform the same level of functionality that will eventually be provided by the PRISM implementation.

In this sense PRISM for depot remains in the "application silo" stage of IT maturity even after having gone through a major ERP installation. Since the PRISM "go-live", several iterations of task forces have been sponsored in attempts to establish standard depot backbone strategy. Most recently, the PRISM Executive Council has launched a focused effort on solving the challenge at the enterprise level, as this is not a problem that can resolved separately by the depot businesses. The expectation is a PRISM depot roadmap by the end of 2011.

6 Depot Project Review

This chapter describes the proof of concept project that was carried out as part of the research in an investigation of application development aimed at business process alignment. As part of the research, a broad set of facilities were surveyed in order to set a baseline for comparison across business units and programs. From this baseline assessment, the scoping of the project, project selection and project process are explained in detail.

6.1 Baseline Survey of Depot Operations

Historically depot processes were managed primarily outside the formal business systems which resulted in significant variability. To get a fundamental understanding of the working level details of depot operations, an extensive six week benchmarking study was conducted across the Raytheon SAS, RMS and NCS sites that are currently managing depot operations within the SAP PRISM infrastructure. During the study, 15 depot lines were observed in El Segundo, CA; McKinney, TX; Forest, MS and Tucson, AZ. Over 50 interviews were conducted with operators, supervisors and production support staff. Additionally, at each of the lines both physical processes and information exchanges were documented. After analyzing processes for all lines, a common logical grouping of activities emerged that was common among all programs. The depot activities could be divided into four categories (Figure 5):

1) ***Material Induction*** – Activities related to receiving depot material from the customer to the manufacturing line.
2) ***Depot Demand*** – The process of diagnostic testing and defect identification, along with order processing for any material needed for unit repairs.
3) ***Depot Supply*** – The process of repairing damaged parts or receiving replacement parts.

4) ***Material Ship*** – The activities related to assembling and shipping a repaired unit back to the customer.

For each line, each of the four process categories was documented at a more detailed level, step by step as a set of value stream maps (Figure 6).

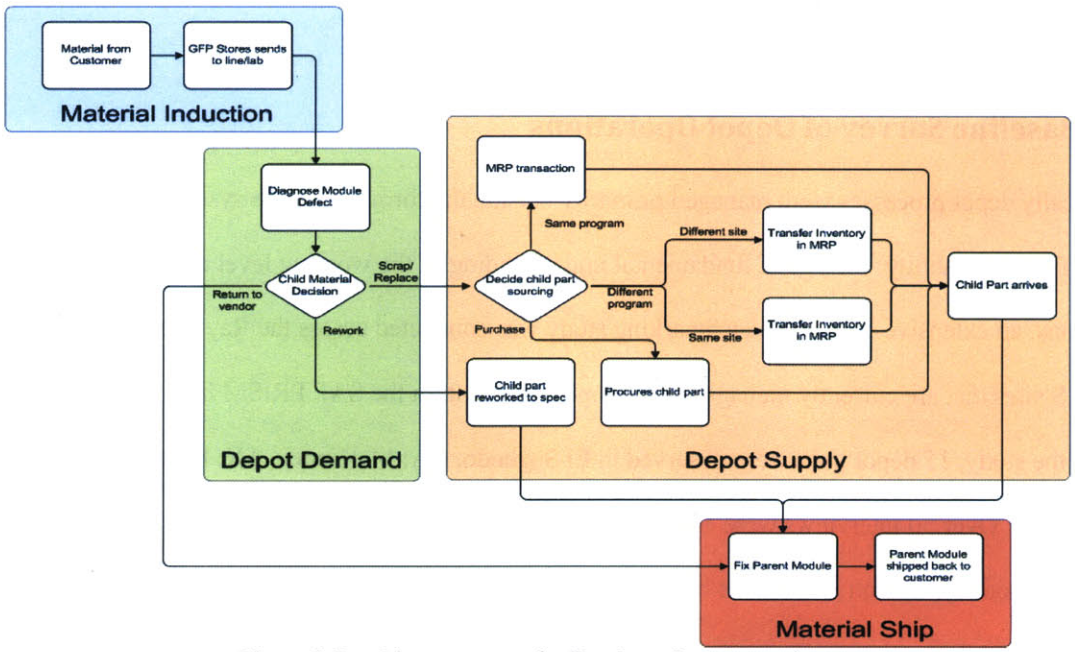

Figure 5: Level 0 process map for Raytheon depot operations

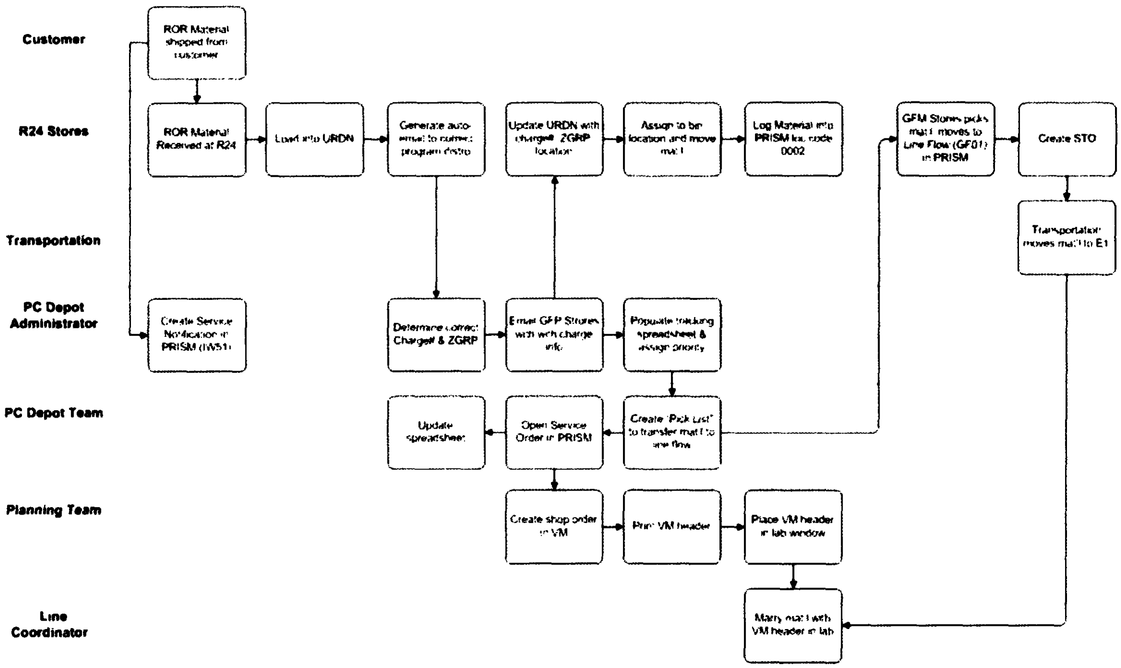

Figure 6: Example of a Level 1 value stream map of Raytheon "depot demand" process

6.2 Observations

Through the study, it was confirmed that depot business processes are highly varied throughout the organization. As mentioned in chapter 5.2.3 the lack of automated integration between PRISM and VM in depot operations is an opportunity for improvement in two specific areas:

First, creating standard IT tools to efficiently process depot work on the floor. Integrating this process set will eliminate the need for double and sometimes triple data entry for the same data element. As a result operators and line supervisors make do with the tools they were given and struggle to keep up with the workload. For example, in the production instance of VM when an operator performs an assembly process on a unit and installs a subcomponent, that subcomponent is removed from the inventory record within PRISM and "consumed" into the unit. All records in PRISM and any integrated systems are automatically updated to reflect the change. However for a similar operation in the depot instance of VM where there is no data linkage, the subcomponent gets installed into the parent unit with no reflection of the material consumption in SAP or in any other system. Since PRISM remains the official central inventory control system in depot, a business process must be developed to ensure that the records in VM and PRISM remain consistent. Based on the study, in the best case situations, a dedicated workforce struggles but has enough bandwidth to maintain fairly accurate records in both systems. In the worst case scenarios, errors can be created which are not caught until later in the process making them more difficult and time-consuming to rectify.

The second opportunity area is the creation of an enterprise-wide, accessible central data store to collect and retrieve information relevant to depot operations. More so than with production contracts, depot contracts can vary widely in scope and customer requirements. For example some contracts may be structured around offering incentives or penalties for turnaround time. This may be the case for break/fix contracts on mission critical hardware. In this scenario, depot reporting capability is limited and it is difficult to query the required data from multiple un-integrated systems. Other contracts may require that the customer have hardware status visibility throughout the depot process. This can be challenging to accommodate due to the sensitivity of in-house Raytheon data and the firewall restrictions of allowing outside access.

To manage around the situations like those mentioned above, depot teams across the company have developed homegrown systems out of necessity. These systems range in complexity from simple manually updated spreadsheets to complex databases. In many cases these home-grown solutions have been developed using funding allocated from departmental budgets and are fully supported by staff engineers. In a survey of over 27 employees supporting depot throughout Raytheon, twelve custom depot management software tools were identified. Furthermore ten out of 27 respondents indicated that they were heavily dependent on desktop spreadsheets for daily line management. The following additional comments collected through the survey provide a strong indication of how pervasive custom applications are:

> "We use a spreadsheet for this but it's tough to keep it up to date the way an automated report would."
>
> "We are developing our own because what is offered right now isn't sufficient to use to make important decisions regarding inventory, etc..."
>
> "We use a Homegrown database developed for [depot]"
>
> "VM Cognos Adhoc Wip report."
>
> "Currently use CPT Database to track material by Program, contract, and date inducted into work. WIP location extracted from VM manually."

6.3 Defining Scope

Based on the observations described in section 6.2, it is clear that depot could benefit from an infrastructure project that integrates PRISM with other adjacent systems much like the production version. Furthermore, the depot business is also in need of specific tools to help the user community manage the unique set of customer requirements. Since this type of major investment could take years to implement, this project was scoped as an interim approach to adopting diversified operating model with a standard customer front end and integrated back end.

The goal of the project was to promote business process alignment by implementing a proof of concept application that addresses a common depot business need and replaces a currently non-standard set of processes. The method to accomplish this was to be based on an architecture that extracts data from isolated systems to create a common user interface rather than by creating an interface between the isolated systems themselves. In promoting aligned business processes in the depot programs scattered throughout Raytheon, the potential benefits of the project include:

- Standard processes promote education, communication and sharing between programs
- Better information for agile decision making
- Improved execution through enhanced performance measures and information about long term trends
- Reduction in IT spending and labor requirements

6.4 Prioritization Methodology Considering Business Process Alignment

In most large organizations, IT governance models are used to make important investment decisions that align with the strategic objectives of the firm. A good governance model utilizes an objective, consistent framework that weighs project benefits against potential risks.[27]

The project prioritization methodology presented in this work is intended to serve as a proof of concept model for consideration in an organization which places a high importance on business process alignment as a strategic objective. The methodology used to select a proof of concept application was a three phase approach.

Phase one - The initial depot benchmarking study and value stream maps were analyzed to highlight 11 enhancements common across the majority of programs that could be the source of potential projects (Figure 7). These gaps were identified as a significant root cause for many of the home-grown work around solutions that have become commonplace within depot.

[27] NCS International. 2011. *AS 8000 Corporate Governance.* Retrieved from http://www.ncsi.com.au/as8000.html

	Reporting / Decision Support Tool	Example
1	WIP Status Reporting	Easy to view status report for all depot WIP by contract
2	Aged WIP reporting	Report showing current WIP sortable by duration since last move or operation
3	In-Line Turn Around Time (TAT) Reporting	Cycle time reporting for in-process depot units
4	Historic Turn Around Time (TAT) Reporting	Cycle Time reporting for completed depot units
5	Historic Customer Hold vs. Raytheon Time Reporting	Customer Hold tracking reports
6	Detailed Cycle Time Drill-Down capability	Detailed cycle time tracking to show where cycle time is accruing across programs in an SPC-like report
7	Contract Fulfillment Reporting	Show/track % fulfillment of retrofit/upgrade contracts by unit or revenue
8	Inventory management reports	Track inventory amount and location for lay-in material
9	Ad-Hoc Query Tools	Ability to easily query PRISM/APEX/VM to create custom reports & queries
10	Defect Tracking	Information to collect/centralize depot failure data for failure mode analysis
11	Equipment Overall Equipment Effectiveness (OEE) tracking for depot vs. production	Ability to view equipment and employee utilization for depot vs. production material on shared resources

Figure 7: 11 identified IT gaps across Raytheon depot operations

Phase two - The 11 opportunities were then evaluated to filter out potential projects with a perceived low return on investment. To approximate this, the projects were compared against a modified two dimensional cost versus benefit matrix. To quantitatively capture relative benefit, a survey was given to a group of 27 depot program support staff representing multiple functional roles spanning 15 depot programs. Each of the respondents was asked to rate each of the projects with respect to relative "need" on a scale from one to ten ranging from lowest need to mission critical need. To quantitatively capture relative "cost", a group of 10 IT managers with depot and manufacturing experience were interviewed independently and asked to estimate the relative effort required to develop a production solution for each of the needs based on expected hardware and software costs, programming requirements and available resources. The results were plotted and organized into three natural groupings (Figure 8). The two projects with a relatively high cost and low need were deemed "low priority" projects and filtered from the list of needs. Of the remaining needs, four were identified as potential "quick wins" as they had a low relative cost and high relative need. The other five needs were rated as medium to high for both relative cost and relative need. These were labeled as "strategic projects" as they would require more of an investment in production, but would have a significant impact to operations.

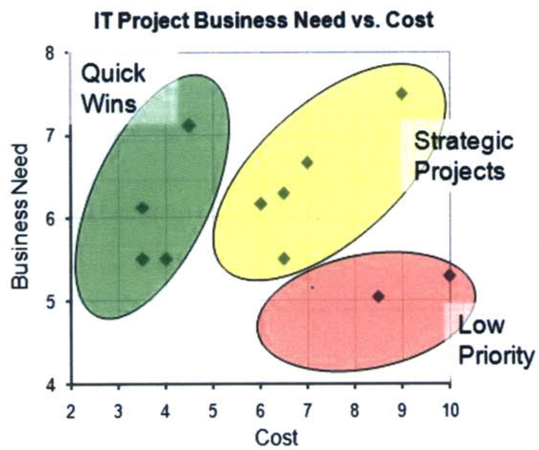

Figure 8: Plot of 11 identified IT opportunities (need vs. cost)

Phase three – The next step was to review the remaining nine projects with respect to their potential for business process alignment. To assess this quality, the same group of IT managers were surveyed and asked to rate each project from one to ten[28] based on 1) The project's usefulness to the entire depot community (not just a specific program) and 2) its ability to be used as a building block for future projects. This rating is referred to as a project's "infrastructure alignment" rating.

[28] The "infrastructure alignment" rating was later scaled down by a factor of 10 in order to calculate the overall project composite score.

To compare the "infrastructure alignment" rating against a single representation of project return on investment, the "need" rating and "cost" rating were collapsed into a single investment utility measure, a formula was applied as a proxy for return on investment:

$$U_i = \frac{\left(\frac{X_i - \mu}{\mu}\right)}{2} + 0.5$$

where:

$$U_i = \text{Investment Utility for Project } i$$

$$X_i = \frac{\text{Need Rating}}{\text{Cost Rating}} \text{ for Project } i$$

Figure 9 shows a plot of Infrastructure Alignment Rating vs. Investment Utility where it can be observed qualitatively that desirable projects are those ranking high in both alignment and investment utility.

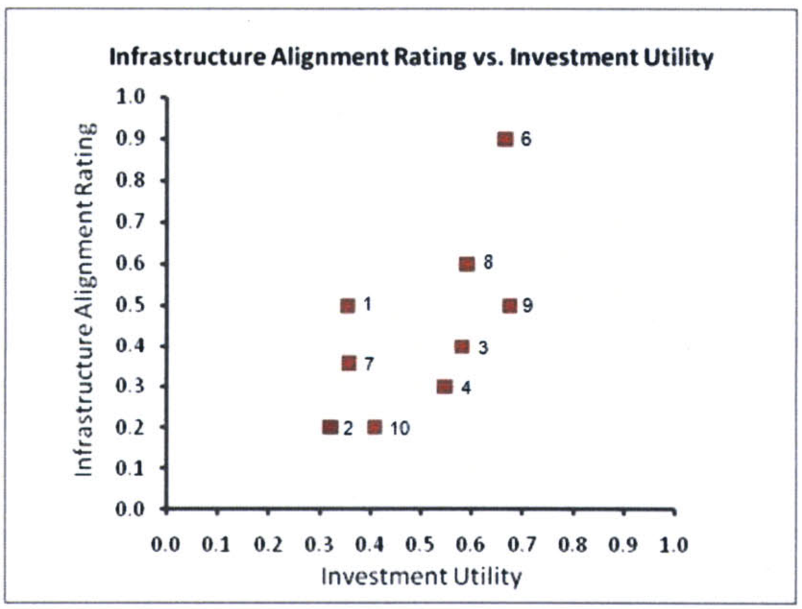

Figure 9: Plot of 11 identified IT gaps (infrastructure alignment vs. investment utility)

To arrive at a final quantitative ranking of the projects a composite score was calculated for each project by taking the product of the Investment Utility Rating and the Infrastructure Alignment Rating (Table 1).

Table 1: Composite priority scores of 11 identified IT gaps

Project	Investment Utility	Alignment Rating	Composite Score
6	0.66	0.90	**0.60**
8	0.59	0.60	**0.35**
9	0.67	0.50	**0.34**
3	0.58	0.40	**0.23**
1	0.36	0.50	**0.18**
4	0.55	0.30	**0.16**
7	0.36	0.30	**0.11**
10	0.41	0.20	**0.08**
2	0.32	0.20	**0.06**

6.5 Project Selection and Description

Based on the project prioritization methodology, the project that had the highest composite score was a project that would enable depot program support staff to drill down into detailed historic cycle time data in order to get gain insight as to where depot units were spending the most amount of time while in Raytheon. In order to do this, a common definition of event level depot activities would be needed, allowing for aggregation by relevant depot unit attributes. Not only did this project have the highest prioritization score, but it also made intuitive sense in the context of the other proposed projects. By focusing on a project that would standardize event level data for analytic capability, the project would enable other applications to use this common event data thus driving commonality and alignment.

At the time of the study, relevant event level data for depot material existed in multiple data systems and was not centrally collected in an organized manner. This presented a challenge within depot as a significant number of contracts are structured with incentives for fast turnaround time. Because centralized data was not readily available, many depot programs maintain unique databases to track material and report on unit status.

The goal of this project was to create a standard event data set and proof of concept dashboard prototype, demonstrating capability for end-to-end depot cycle time drill-down reporting that could feasibly replace the existing work around solutions.

6.6 Project Process

This section describes the steps taken throughout the project. Details related to the prototype design, testing and deployment are presented.

6.6.1 Design

The first step in the project was to better understand the needs of the user community and to define the high level architecture. Following additional interviews and further discussion with IT subject matter experts, the project was broken into two major components:

1) **A standard event data set** would be generated by batch data imports from existing enterprise data sources. The design of the event data set would include the necessary logic to create a chronology of relevant depot unit activity.
2) **A standard portal** enabling the depot user community to view metrics that are meaningful to managing their programs.

Further detail regarding the design of each of these components is provided in the following two sections.

6.6.1.1 Standard Event Data Set

To gather detailed requirements for the design of the standard event data set, further interviews were conducted with depot representatives to understand the types of events that could be considered important and should be included. Concurrently, technical workshops were conducted in order to gather information regarding what types of data were available within the enterprise systems and to understand the methods by which it could be accessed.

It was found that all relevant inventory and location data and shop floor events were contained within the PRISM and VM systems, respectively. Between the two systems, a list of 29 unique transaction codes were isolated for retrieval with 35 event attributes being collected per transaction. Events that were captured included goods receipts from the customer, goods shipped back to the customer, operation start and complete timestamps, hold status changes, as well as many other event types.

Custom logic was applied in order to translate unit event sequences into activity categories, ensure all time periods were accounted for, and realign overlapping signals (Figure 10). For the proof of concept model, the data import logic was applied to a sample set of 35 representative depot units across the SAS and RMS business units to generate a prototype data set.

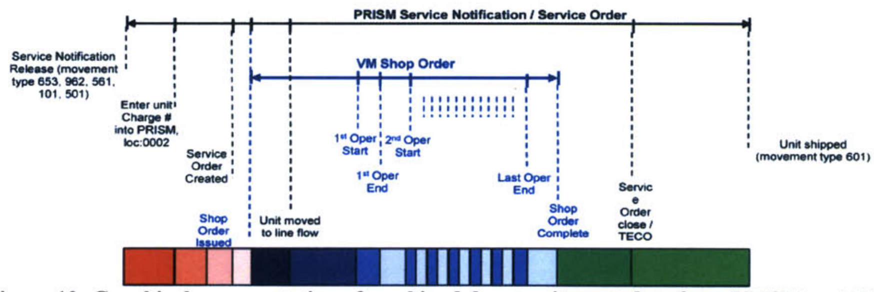

Figure 10: Graphical representation of combined depot unit event data from PRISM and VM

6.6.1.2 Standard User Portal

The benefit of having a standard centralized data set is that it enables flexibility in reporting in that front end dashboards can be created with little development effort. However, to promote alignment throughout

Raytheon it was considered important to have a standard user portal that addressed the most frequent business processes with a common look and feel.

There were two decisions to be made when considering the design of a standard user portal or dashboard: First, what metrics should be available? Second, what will the user experience be both in terms of software and interface look and feel?

To gather specific requirements for what metrics should be available in the portal, four focus groups of depot program managers spanning multiple depot sites and program families were interviewed. These focus groups were selected because they had indicated a strong need for this type of application in initial interviews and surveys. The buy-in and support of these groups would be critical as it was expected that they would be early adopters and potential advocates of this new capability. By engaging them in the design process early, the likelihood of adoption by the general depot user community would be increased.

Based on the initial depot process value stream mapping along with focus group interviews a set of standard dashboards were defined. For each dashboard, a navigation path was also defined allowing users to access summarized data at aggregation levels that made sense for their management activities. Descriptions of dashboard reports, navigation paths, and data aggregation levels are shown in Table 2.

Table 2: Dashboard feature summary

Dashboard	Description	Navigation Path	Data Aggregation Levels
Unit History	Timeline of time accrual between each event transaction. Each duration spanning adjacent event transactions is assigned an activity code allowing for higher level aggregation and trending analysis.	Status -> Business Unit -> Program -> Contract ID -> Unit Serial No.	Unit Part no./Serial No.
Cycle Time Trending	Run chart displaying time series of accrued cycle time for depot units sorted by goods recepit data on horizontal axis.	Status -> Business Unit -> Program -> Contract ID -> Unit Serial No.	Business Unit, Program, Contract ID
Pareto Analysis	Aggregated report displaying summarized cycle time accrued by activity code. To be used in identifying process areas that have high contribution to overall depot cycle time.	Status -> Business Unit -> Program -> Contract ID -> Unit Serial No.	Business Unit, Program, Contract ID

The other decision to be made was with regard to the dashboard design as well as interface look and feel. Under the guidance of the IT and Business Intelligence (BI) leadership team, the decision was made to develop flash based[29], interactive dashboards using the SAP dashboard design software suite, Xcelsius[30]. The business intelligence team was in the final stages of evaluating the transition of much of the existing reporting infrastructure to Xcelsius, so it was a natural synergy to align depot reporting with the new standard. The depot dashboard prototype development also had the benefit of providing another source of feedback for the BI migration team. The look and feel of the dashboards was to follow the Raytheon standard template as designed by the BI team, including Raytheon themed headers and footers and a standard page layout (Figure 11).

[29]The term "flash based" is in reference to being based on adobe flash runtime player http://www.adobe.com/products/flashplayer/

[30] SAP Community Network. 2011. *Business Intelligence: Dashboard Design (Xcelsius)*. Retrieved from http://www.sdn.sap.com/irj/boc/crystal-dashboard

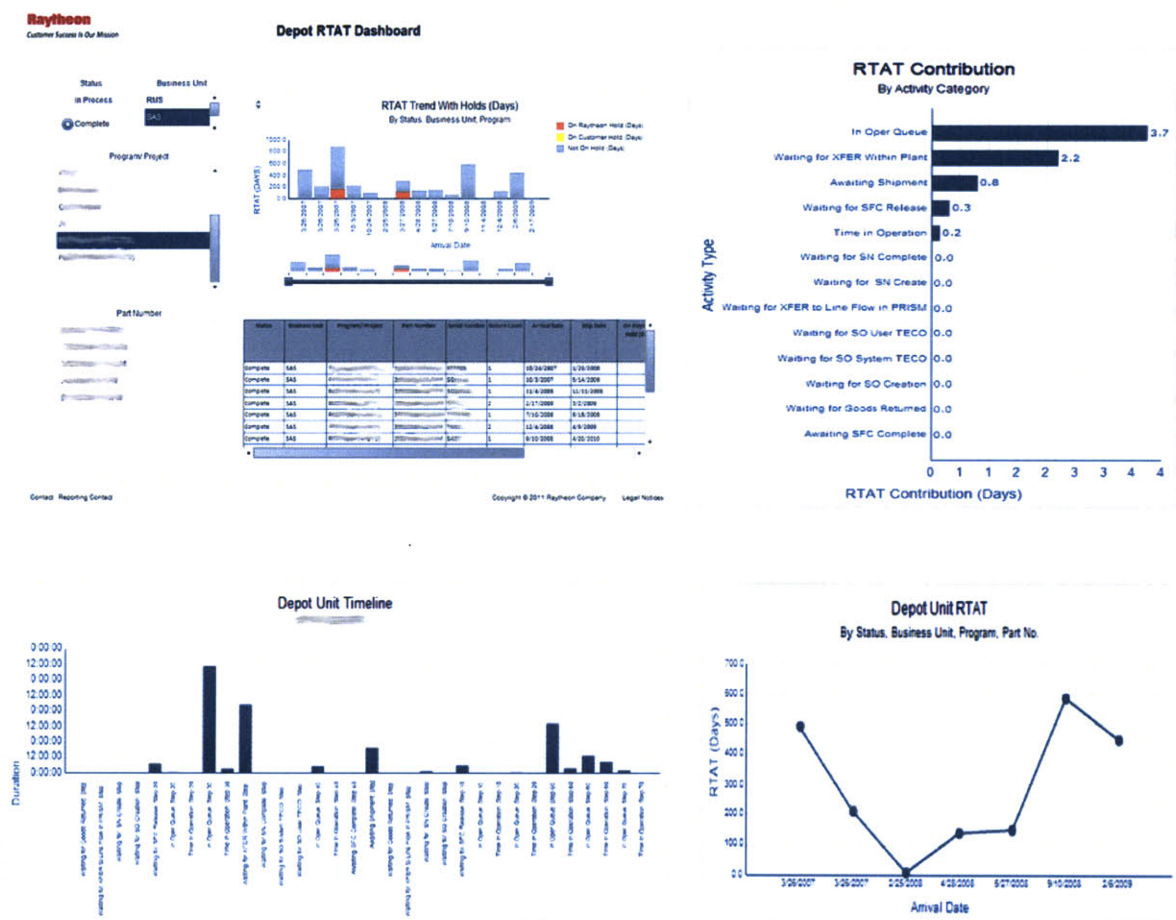

Figure 11: Screenshot of proof of concept depot dashboard web portal

6.6.1.3 Proof of Concept Prototype Architecture

Although it would be preferred to launch a broader pilot system in an environment that closely mirrors production, the timeline available for the research in this thesis was prohibitive in doing so. For the proof of concept prototype, a local representation of the production system architecture was installed on a standalone computer to enable high flexibility in development (Figure 12). For the event data set, a Microsoft Access database was developed to import depot transaction data and to apply logic for filtering and categorizing unit activities. An ODBC connection was set up to import data directly from the VM data repository and a batch run of transactions were run to import inventory and location data from the SAP data repository. In a production environment with much higher volumes of data, a likely architecture would include a tightly controlled batch import of data into a data warehouse where a set of computational processes would transform the raw data into the desired centralized event data table.

The Xcelsius dashboards were run locally on the pc, using the MS Access database as the data source. In a production environment, the report flash files would be stored centrally within the enterprise reporting structure, and client web portals would be used to remotely access the data.

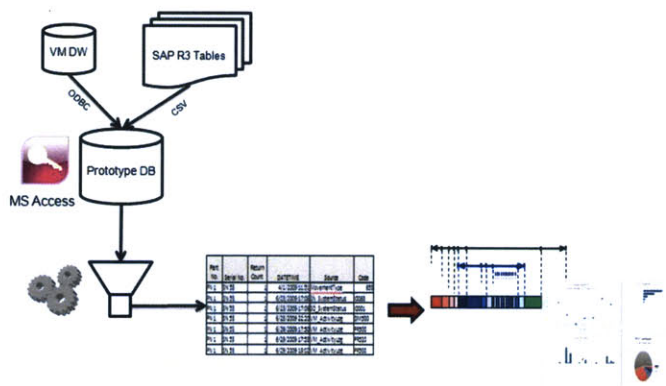

Figure 12: Representation of proof of concept prototype architecture

6.6.2 Testing

The 35 depot units used in the sample data set were intentionally selected in order to cover wide ranging scenarios of depot activity, representing some of the most extreme situations and event sequences that can occur within depot. The key elements of the proof of concept model that were tested were the data import and the logic applied to the data to create the event data set. For the prototype model, all imported data (5000 rows) was manually verified against the source database. Furthermore a manual review of each event sequence and each unique combination of events was performed. No systematic issues or gaps in cycle time data were observed.

6.6.3 Proof of Concept Deployment and Customer Feedback

Upon completion of the project, several venues were chosen to showcase the proof of concept application. Live demonstrations were conducted for the focus groups that contributed to defining the requirements for the portal. Additionally several "lunch and learn" sessions and webinars were carried out reaching over 70 employees within the depot community.

Following proof of concept deployment, an on-line survey was distributed to attendees in order to gather quantitative and qualitative feedback from the user community. The survey was designed to provide qualitative and quantitative measurements of 1) the likelihood of adoption if implemented in a production environment and 2) the impact that the application would have to depot operations. Of the 70+ surveys sent out, eight responses were received. Based on the survey results and the volume of positive feedback during the dashboard demonstrations, it can be concluded that a production implementation would be welcomed within the depot community and would make a significant impact in both capability and labor savings.

6.6.3.1 Quantitative Survey Feedback

In terms of adoption likelihood, while not definitive, the responses to the scaled rating questions below indicate that a high adoption rate would be likely.

> When asked, "How would you describe the usefulness of the dashboard drilldown reports for tracking depot activity (1 = not useful, 5 = extremely useful)?" the average response was 4.8 out of a possible 5.0

> When asked "How likely would you be to use the RTAT drilldown reporting if available (1 = not possible, 7 = definite)?" the average response was 6.25 out of a possible 7.0.

When asked if the new capability would enable depot operations to uncover systematic inefficiencies or problems that they wouldn't have otherwise been able to detect, all eight respondents answered "yes".

In terms of labor savings, six of the eight respondents indicated that they actively maintain a spreadsheet to track depot activity that is primarily comprised of data pulled manually from PRISM and VM. Furthermore when asked "How much time do you spend per week (average) collecting and analyzing data similar to that displayed in dashboard drilldown reports?", the average response was 4.75 hours per week. When followed up with the question, "How likely is it that these dashboards/reports would reduce your usage of off-line tracking of depot units (1 = not possible, 7 = definite)", the average response was 5.8 out of a possible 7.0. Applying these results and assuming a conservative estimate that a 50% reduction in manual analysis could be achieved, this translate into 285 hours per week in productivity improvements, extrapolating across SAS alone [31]

6.6.3.2 Qualitative Survey Feedback

In addition to scaled rating questions, qualitative responses were collected to capture user concerns and feedback. When prompted about increased visibility systematic manufacturing inefficiencies, the following comments were supplied:

> "I think the operators and depot managers would only increase their diligence if encouraged/enforced by their management. If factory management sees a benefit, it will get done."

[31] 600 Depot contracts / 5 contracts per depot manager * 4.75 hrs./week * 50% reduction = 285 hrs/week (14,820 hrs/yr)

"Queue times by operation … are especially helpful. Reporting on these could reveal issues with factory flow, materials scheduling, materials replacement, material handling issues (i.e. handoffs), workforce scheduling, etc. We do not have any reports that provide this currently, either on production or depot side."

"I think this type of reporting is mostly [valuable for] uncovering process inefficiencies, but systemic problems like broken links or information not populating correctly (automation) could be discovered."

"I really think it's great! I hope we can take it and keep going with it, because I really think it could do a lot for depot activities for Raytheon."

7 Conclusions and Recommendations

7.1 Conclusions

This work explores the role of major IT infrastructure investments in industry today and the challenges that arise when implementations do not go as planned. Several frameworks for evaluating enterprise IT architecture were considered and applied to a case study ERP implementation across several divisions within Raytheon.

Two sides of the implementation were presented. One implementation was heralded as a great success as it had relatively straight forward integration requirements and heightened management support. This system is used today to create value throughout the organization and serves as a competitive advantage in the market.

The other side of the story reveals an implementation that proved much more difficult to execute, ultimately resulting in a fragmented set of business processes tied to a portfolio of isolated IT architectures.

However the results of this thesis prove that although a central rationalized data platform is the ideal for an IT enabled company, it is possible to align business processes without depending solely on perfecting the underlying system integration. A tool was developed that establishes a common business process across dozens of fragmented product lines serving as a proof of concept for future projects throughout the organization.

Furthermore the project within this thesis demonstrates that employees create work-around applications out of necessity and when provided with a more user friendly, efficient business process they will seek it out. When embarking on a project of aligning business processes or creating new ones, if the customer's voice is heard and the end result improves employee lives, they will likely adopt the change rather than resist. The project presented in this case got the depot community excited and engaged in the continuous improvement of program operations and can serve as an example for greater progress in the future.

7.2 Recommendations for Steps going Forward

Although Raytheon has come a long way on its journey toward becoming an organization that can leverage its Information Technology infrastructure as a competitive advantage, it is recognized within the organization that there are many more available opportunities. This section provides both short term and long term recommendations for Raytheon operations, particularly within the depot program management studied in this research.

7.2.1 Short Term Recommendations

Unite the Depot Community

During the depot benchmarking study and proof of concept project, a key observation was made that because of the manual nature of most depot operations, there exists a significant opportunity to automate and integrate the current state depot processes into the PRISM environment thus optimizing both the process and the human capital of these activities. Depot programs are generally aligned managerially with the parent programs that they support. Furthermore the organizational dynamics described in section 3.4 contribute to the insulation between depot programs. By re-engineering, integrating and automating these processes a broader network of practitioners will be created to enhance the depot business. It is the recommendation of this work that Raytheon utilize the connections that were established through benchmarking and demo activities described here to launch a formal depot communication channel where best practices can be shared and business process gaps can be more easily identified.

Build off of Project Momentum

The project presented in this thesis was met with great enthusiasm by people throughout the depot community. It is widely recognized that an improvement is needed, but enterprise integration is costly and time consuming. It is our recommendation that Raytheon build off of the momentum generated with this project and not only implement a production version of the pilot, but also to use it as a lightning rod to encourage future projects promoting depot alignment.

Clean and Standardize Data

One of the major challenges through this work was in interpreting non-standard data and discerning if the data source could be trusted or not. Different depot programs use the current standardized systems for different applications tailored to their needs. For example a program may use a database field in SAP to store customer hold data because they are not using it for anything else. Meanwhile in another part of the organization under the same instance of SAP the field is being used for a critical application. This type of situation can make it extremely difficult to parse data when extracting it for analysis or in future application development. Having a culture of data system discipline is critical in the transformation into a rationalized data architecture where the IT environment allows agile application development to create value for the firm.

7.2.2 Long Term Recommendations

Depot IT Integration

The most obvious, but most costly improvement that can be leveraged to Raytheon depot would be to launch an enterprise depot integration effort, unifying Raytheon depot under one common platform. Re-engineering depot processes to create a robust, agile set of enterprise practices utilizing PRISM can accomplish the same objective without the disruption of an organizational realignment. However, this requires the commitment of the Raytheon businesses to design and implement a common roadmap in order to truly bring the depot system architectural maturity to the point where it can create value for Raytheon in the growing market.

More Investment in Business Intelligence Capability and Responsiveness

Establishing SAP PRISM as the central platform of the organization was a significant investment for Raytheon. By and large the venture has been very successful and the system serves as the transactional backbone of the business. Another area of opportunity is to further investment in the BI infrastructure to bring it up to the level of the core transactional system. To leverage the centralized data within the enterprise systems, BI capability must be improved to the point where quality business applications can be developed quickly to meet the changing needs of the business.

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