A Case Study: Creating Momentum And Self-Sustaining Change In Product Development Through Continuous Improvement Efforts

by

Steven Lee

B.S. Life Sciences, United States Military Academy, West Point, 2001

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

Master of Business Administration
and
Master of Science in Engineering Systems

In conjunction with the Leaders for Global Operations Program at the Massachusetts Institute of Technology

June 2011

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

Certified by _____
Deborah Nightingale, Thesis Supervisor
Professor of the Practice, Aeronautics and Astronautics and Engineering Systems Division

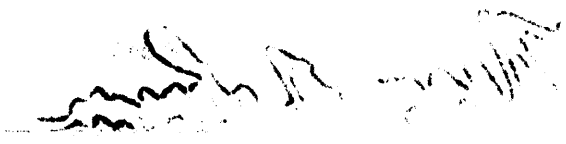
Certified by _____
Roy Welsch, Thesis Supervisor
Professor of Statistics and Management Science, MIT Sloan School of Management

Certified by _____
Jan Klein, Thesis Reader
Senior Lecturer, MIT Sloan School of Management

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

This page intentionally left blank.



A Case Study: Creating Momentum And Self-Sustaining Change In Product Development Through Continuous Improvement Efforts

by

Steven Lee

Submitted to the MIT Sloan School of Management and the Engineering Systems Division on May 6, 2011 in Partial Fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Engineering Systems

Abstract

Traditionally, in Raytheon's Integrated Defense System Product Development Engineering Group, lean initiatives have not been fully adopted. Though the lean tools are useful, the engineering group is looking for more effective deployment methods to implement lean.

The conventional push approach is to have management communicate some strategic objective which generates a project. Historically, a useful lean tool is developed and introduced, but is *under*-utilized months later. We focused on implementing a push-pull hybrid approach. The purpose is to merge the strategic objectives with stakeholder values to generate a project that addresses needs from both ends.

Organizations (such as Toyota) that are effective with change management typically spend 80 percent of their time and resources on people engagement and organizational architecture. The remaining 20 percent is spent on lean tool utilization. Raytheon emulated this model and generated initial people engagement. We discovered that successful change management embodies three factors: 1) Engaging Stakeholders 2) Engaging Leaders 3) and Ensuring Alignment of Organizational Architecture.

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

Thesis Supervisor: Roy Welsch
Title: Senior Lecturer, MIT Sloan School of Management

Thesis Reader, Jan Klein
Title: Senior Lecturer, MIT Sloan School of Management

This page intentionally left blank.

Acknowledgments

Leaders for Global Operations: The author gratefully acknowledges the support and resources provided by the MIT Sloan School of Management, MIT Department of Systems Engineering, and the Leaders for Global Operations Faculty.

Raytheon, Integrated Defense Systems: The author would like to acknowledge the support from Raytheon personnel with resources, time, and invested support and engagement from many stakeholders. The author specifically thanks Kurt Mittelstaedt, Mike Yeomans, Mike Kelly, John Day, and Charlie Mullins for the unwavering support and commitment to this change initiative. The author hopes that the time spent at Raytheon was worthwhile and has provided contribution and value to the product development organization.

Thesis Advisors: The author is extremely grateful to Professors Debbie Nightingale and Roy Welsch for their unwavering support and candid discussions. During times of difficulty and self-doubt, both have made a significant impact to my personal development and ability to contribute to Raytheon.

LGO Class of 2011: The author would like to thank the class for the unwavering support inside the classroom as well as beyond it. Best of luck to the 2011 LGO Class: you will be missed.

Family: The author would like to thank his wife, Joyce Kim, for the steadfast dedication during extremely busy times and for the unending understanding. Her love and respect have been the impetus to keep pushing during very difficult and challenging times, as the LGO Program demands from its candidates.

This page intentionally left blank.

Biographical Note

Steven Lee, born in Seoul, Korea, migrated to the United States with his family at age 1. After finishing high school, in Riverside, CA, he chose to attend the United States Military Academy at West Point, NY. There he earned his Bachelor's of Science degree in Life Sciences. As a cadet, Steven spent his summers training in military professional schools such as Airborne School (parachuting out of C-130 airplanes) and Air Assault School (repelling out of Blackhawk helicopters). He also served near the De-militarized Zone between North and South Korea, as a tank platoon leader for several months. During the last summer as a cadet, Steven, served at Walter Reed Medical Center in Washington, D.C. doing rotational assignments with medical doctors.

Upon graduation, Steven was commissioned as a 2nd Lieutenant in the United States Army and served as an Armor (tanks and cavalry) Officer. He spent a year in Kentucky doing his Officer Basic Course and Scouts Leaders Reconnaissance Course. Later he reported to his first real Army unit at Fort Lewis, WA where he served in many capacities. His work experience in the military included: combat leader of troops, supply chain management, procurement, transportation and logistics, and operations planning. In 2004-2005, Steven deployed to Iraq, in support of Operation Iraqi Freedom III, where he spent the majority of his time planning for the elections in Mosul, Iraq for 3 million Iraqi citizens by coordinating security operations among 15,000 U.S. and multinational forces spanning an area of operations of 24,000 square kilometers.

After serving five years line the Army, Steven was honorable discharged and moved to Phoenix, AZ to work for Honeywell International in the Aerospace sector. There he worked in the supply chain division, as he was in charge of the Pull Initiative, one which focused on placing over 500 of Honeywell's suppliers on a consumption-based order management system. After that assignment, Steven became an operations manager and managed six supervisors and led a team of 37 individuals spanning nine

departments producing aircraft engine components. Steven is Six-Sigma Green Belt Certified and Black Belt Trained.

After three years at Honeywell, Steven applied to business schools in 2008, and in the following summer he matriculated into the Leaders for Global Operations (LGO) program at MIT. Upon graduation, Steven plans to work for Cisco Systems in Silicon Valley, CA where he hopes to use his recently acquired operations knowledge to contribute to the growth of that organization.

This page intentionally left blank.

Table of Contents

Abstract 3

Acknowledgments 5

Biographical Note 7

Table of Contents 10

List of Figures 12

1 Introduction 14

1.1 Industry and Company Overview 14

1.2 Current State 16

1.3 Problem Statement 17

1.4 Thesis Overview 18

2 Motivation 20

3 Approach 21

4 Choosing the "Right Project" 26

4.1 Understanding the Organization: A Three Lens Analysis 26

4.2 Personal Stakeholder Values 32

4.3 Use Information Gathered to Choose the "Right" Project 37

5 Choosing the "Right" Group 39

6 Engage Leaders 43

6.1 The X-Matrix 43

6.2 Modification of Strategic Objectives 47

6.3 Modification of Metrics 48

6.4 X-Matrix with Modifications 54

7 Keeping Stakeholders Engaged Through Project Execution 57

7.1 Project Execution 57

7.2 Examining Failure Modes 66

8 Recommendations: Making Raytheon Six-Sigma Training Even Stronger 69

9 Knowledge Transfer 71

10 Conclusions and Next Steps 75

10.1 Conclusions and Key-Takeaways 75

10.2 Next Steps and Future Opportunities 75

11 Contributions and Benefits to Raytheon 77

12 References 78

List of Figures

Figure 1: Major Defense Industry Competitors (By 2009 Expenditures) 14

Figure 2: Push-Pull Hybrid Approach 21

Figure 3: Integration of Quality Control and Continuous Quality Improvement 23

Figure 4: Stakeholder Importance vs Performance 28

Figure 5: Example of a Matrix Organizational Chart 29

Figure 6: Stakeholder Mapping 31

Figure 7: Project Commitment Chart 32

Figure 8: The Impact of Values Clarity on Commitment 33

Figure 9: Stakeholder Interview Template 34

Figure 10: Stakeholder Interview Results 36

Figure 11: QFD Matrix 38

Figure 12: Relationship Between Time and Engagement 39

Figure 13: Social Network Analysis Example 40

Figure 14: Social Network Analysis Exercise 42

Figure 15: X-Matrix (Current Condition) 44

Figure 16: Mis-alignment of Stakeholder Values to Strategic Objectives 45

Figure 17: Mis-alignment between Strategic Objectives and Metrics 46

Figure 18: Mis-alignment between Metrics and Key Processes 47

Figure 19: One Page Performance Metrics 50

Figure 20: Nine Block Rating Scheme 51

Figure 21: X-Matrix (Proposed Condition) 56

Figure 22: Screenshot of the 5S Checklist 61

Figure 23: Differences Between Lean in Manufacturing and Engineering 62

Figure 24: Value Stream Mapping in Raytheon's Electrical Directorate Design 65

Figure 25: Failure Modes Effects and Analysis in Raytheon's Electrical Design Directorate 67

Figure 26: Modified Raytheon Six-Sigma Process 69

1 Introduction

1.1 Industry and Company Overview

Industry:

Raytheon competes in the defense contractor industry, which includes products or services to a military department of a government. These products can range from military aircraft, ships, vehicles, radars, weaponry, to electronic systems. Services may include logistics, technical support/training, communications support, and engineering support for the government [1].

Over the past decade, the United States Department of Defense spends nearly $316 billion on contracts [2]. Figure 1 shows that in 2009, Raytheon ranked the fifth largest defense company in the United States generating in excess of $16B [3].

Figure 1: Major Defense Industry Competitors (By 2009 Expenditures)

Rank	Global Vendor Name	Total Dollars
1	LOCKHEED MARTIN CORPORATION	$38,512,401,433.23
2	THE BOEING COMPANY	$21,956,065,368.89
3	NORTHROP GRUMMAN CORPORATION	$19,654,882,647.82
4	GENERAL DYNAMICS CORPORATION	$16,432,366,120.40
5	RAYTHEON COMPANY	$16,106,903,431.28
6	UNITED TECHNOLOGIES CORPORATION	$7,538,417,441.35
7	L-3 COMMUNICATIONS HOLDINGS INC.	$7,469,492,207.53
8	BAE SYSTEMS PLC	$7,030,720,447.92
9	SAIC INC	$6,566,776,579.50
10	OSHKOSH TRUCK CORPORATION	$6,396,926,524.33
11	MCKESSON CORPORATION	$5,253,901,781.68
12	KBR INC.	$4,638,238,836.90
13	BECHTEL GROUP INC	$4,288,347,658.39
14	COMPUTER SCIENCES CORPORATION	$4,154,871,707.63
15	GENERAL ELECTRIC COMPANY	$3,801,724,603.63
16	BOOZ ALLEN HAMILTON INC.	$3,477,544,402.56
17	HUMANA INC.	$3,437,969,127.66
18	CH2M HILL COMPANIES LTD	$3,371,700,097.35
19	ITT CORPORATION	$3,050,526,659.86
20	VERITAS CAPITAL MANAGEMENT II LLC	$2,938,415,700.74
21	HEALTH NET INC.	$2,842,793,177.61
22	HONEYWELL INTERNATIONAL INC	$2,756,985,745.67
23	MACANDREWS & FORBES HOLDINGS INC.	$2,728,652,735.67
24	TRIWEST HEALTHCARE ALLIANCE CORP.	$2,672,212,524.42
25	BELL BOEING JOINT PROJECT OFFICE	$2,620,340,065.85

As evidenced by the figure above, Raytheon is a major player in its industry.

Overview:

Raytheon's core competency is technology and innovation specializing in defense, homeland security, and other government markets throughout the world. Raytheon history spans over 89 years and provides customers with state-of-the-art electronics, mission systems integration and other capabilities in the areas of sensing, effects, command and control, communications, and intelligence systems, as well as a broad range of mission support services. Raytheon employees 72,000 workers worldwide with a $25 billion revenue stream in 2010 sales [4]. Raytheon is organized into several major divisions:

- IDS- Integrated Defense Systems: innovation in Radio Frequencies uses as applied to radar and communication systems
- IIS- Intelligence and Information Systems: engaged in intelligence, surveillance, and reconnaissance and in creating a worldwide network that supports these capabilities
- NCS- Network Centric Systems: develop optical phased arrays, which enable computer programmable, all electronic steering, and focusing of laser beams for geosynchronous satellites and high-altitude aircraft.
- RTSC- Raytheon Technical Services Company: provides life-cycle support to customers that predict customer needs and reacts to issues the customer faces
- RMS- Raytheon Missile Systems: provides missiles that are capable of engaging moving targets
- SAS- Space and Airborne Systems: provide satellite capability to customers such as NASA [6]

History:

In 1908, a Londoner named Alfred Charles Cossor started a small electronics firm, A.C. Cossor Company, which was first listed as a private company. Over the next 100 years, this privately owned firm

has been pivotal to some of the greatest technological advances in British history, from wireless radio sets to the Chain Home Radar that helped protect Britain during the Battle of Britain.

It was the global turbulence that emerged in the late 1930s that brought Cossor's company together with the United States. Cossor's company was the first to develop the radar capability, a way for radio waves to bounce off of aircraft and the echo interpreted by a receiving station to determine the direction and distance of the aircraft. As the war progressed, the British industry was constrained and unable to mass-produce these radar systems. In the United States, Raytheon had been experimenting with microwave tubes. The MIT Radiation Laboratory suggested a meeting between British scientists and Raytheon engineer Percy L. Spencer. Ultimately, a contract was awarded to Raytheon to supply the magnetrons, the "heart" of these radar systems. As the war progressed, Spencer's Raytheon became the major supplier of magnetrons to Cossor's company in the U.K. In 1961, Raytheon acquired the A.C Cossor Company [5].

Culture:

Raytheon prides itself on the commitment to driving strategic growth, establishment of an inclusive culture, and in the development of an environment for learning. This is based on the need that companies that depend on innovation need to draw on the skills of lifelong learners. A key element of this learning process resides in the Raytheon Six Sigma efforts, which give employees the opportunity to learn about process improvements and providing value to the organization [7].

1.2 Current State

Traditionally, in Raytheon's Integrated Defense System Product Development Engineering Group, lean initiatives have not been fully adopted. Though the lean tools are useful, the engineering group is looking for more effective deployment methods to implement lean in order to increase speed of product development and to cut costs. The conventional push approach is to have management communicate some strategic objective which becomes the basis for project generation.

1.3 Problem Statement

The push approach to change management has some limitations. This approach quite often fails to consider the feedback from the user level. Historically, a useful lean tool is developed and introduced, but is *under*-utilized months later. The purpose of this thesis is to outline an approach that is more effective in changing the motivation of lean efforts to a point where the transformation is more self-sustaining and long-term.

We are focusing on implementing a push-pull hybrid approach. The strategic objectives management develops are paramount. On the other hand, the engineer engagement portion necessary to ***sustain*** the continuous improvement effort is equally vital. The purpose is to merge the strategic objectives with the stakeholder values to generate a project that addresses needs from both ends.
Organizations (such as Toyota) that are effective with change management typically spend 80 percent of their time and resources on people engagement and organizational architecture. The remaining 20 percent is spent on lean tool utilization. We wanted to emulate this model in this setting. To generate initial engagement, we focused much of our time and resources on people. This was done through several mechanisms, which will be discussed later. Below are some general guidelines of the project:

- Project Setting: Foster continuous engagement in the electrical design directorate in Sudbury.
- Project Scope: Scope for project 1 is over two lab groups to engage test engineers to apply lean tools in respective labs. Scope for project 2 is to engage more interactions between test labs, program management, logistics, material handlers, and auditors.
- Purpose: The purpose of these projects is to decrease inspection cycle time and reduce the number of defects and rework.
- Goals/Deliverables:
    1. A framework or model that outlines an approach for momentum for change
    2. Pilot project with a directorate with measurable impact.

1.4 Thesis Overview

The internship and data gathering for this thesis took place in Raytheon's IDS (Integrated Defense Systems) in Sudbury, Andover, and Tewksbury, MA from February-August of 2010. This was in collaboration with faculty members from the Massachusetts Institute of Technology's Sloan School of Management and School of Systems Engineering and personnel in Raytheon's IDS Division. The organization of this thesis is as follows:

Chapter 1 discusses the overview of Raytheon Company and the Integrated Defense Systems Division. The history, current state, and problem statement will be discussed.

Chapter 2 explores the motivation for this research.

Chapter 3 will explore an approach the author will take and discuss some of the barriers to change using the Total Quality Management Model. It will cover the key steps necessary to infuse successful transformation into an organization.

Chapter 4 will discuss how the right project was selected. It will conduct the analysis of Raytheon's IDS current condition using the 3 lens analysis. The results from the stakeholder analysis, organizational design, and a methodology are used to determine the projects with the greatest potential of success and importance.

Chapter 5 will discuss how Raytheon chose the right pilot group(s) to engage using a more analytical approach. Here, the author will discuss the merits and mechanics of a modified and simpler version of social network analysis.

Chapter 6 will explore how the leaders in the organization were engaged through using the X-Matrix to look at the organizational architecture (How well do the strategic objectives, metrics, key processes, and stakeholder values align). The author will discuss the modifications made to Raytheon's strategic objectives, metrics, and ability to re-align key factors to help drive the appropriate change behavior.

Chapter 7 will discuss how stakeholders were engaged in Pilot Projects 1 and 2 and the execution of each of these projects. Project results will be disclosed and demonstrations of how stakeholders were more engaged will be mentioned.

Chapter 8 will discuss the recommendations/modifications that Raytheon should make to their current and conventional Six-Sigma training for new hires to help better drive change initiatives.

Chapter 9 contains the continuity file provided for Raytheon prior to the end of the internship. This includes an explanation of the approach along with key tools used to engage the workforce.

2 Motivation

Raytheon's primary customer base is the United States Military. Based on the evolution of warfare going from a traditional style (where enemies are easily identified by uniforms) to a more guerilla style-type warfare (where enemy combatants are integrated with the civilian population), requires new weaponry and strategies. Today, the United States fights multi-front wars (Afghanistan, Iraq, Korean Peninsula, etc). With the change in war tactics, requires new weapons and capabilities.

Raytheon understands that our military servicemen and women have a deep desire to use the latest technologies to help fight the War on Terror. Because of the severe nature of warfare, Raytheon's motivation is to provide the war fighter with the latest technology in the quickest manner. No longer is it satisfactory to provide a great capability if it cannot get to the user in time.

The motivation for this thesis is to provide Raytheon with an approach to change management and Lean that is more self-sustaining for the purpose of increasing speed of products to market to keep our military service-people safe in combat. It is no longer acceptable simply to design a capability that is perfected. The customer demands that this capability be put into the hands of the users as quickly as possible to help keep them safe and provide enablers to better help accomplish missions.

Many U.S. companies try to emulate the change management process/approach of Toyota, especially when it relates to continuous improvement. Even with all the literature Toyota has provided to the rest of the world, companies still find it very difficult to emulate. This thesis will explore some the reasons why change management is challenging and difficult to emulate and provide a more useful and self-sustaining model to help an organization gain more long-term traction to continuous improvement and lean in the product development group.

3 Approach

The traditional change management approach in Raytheon's Product Development Group in Sudbury has not been as successful as executives wished. As seen in Figure 2, the left portrays the approach Raytheon had taken in the past.

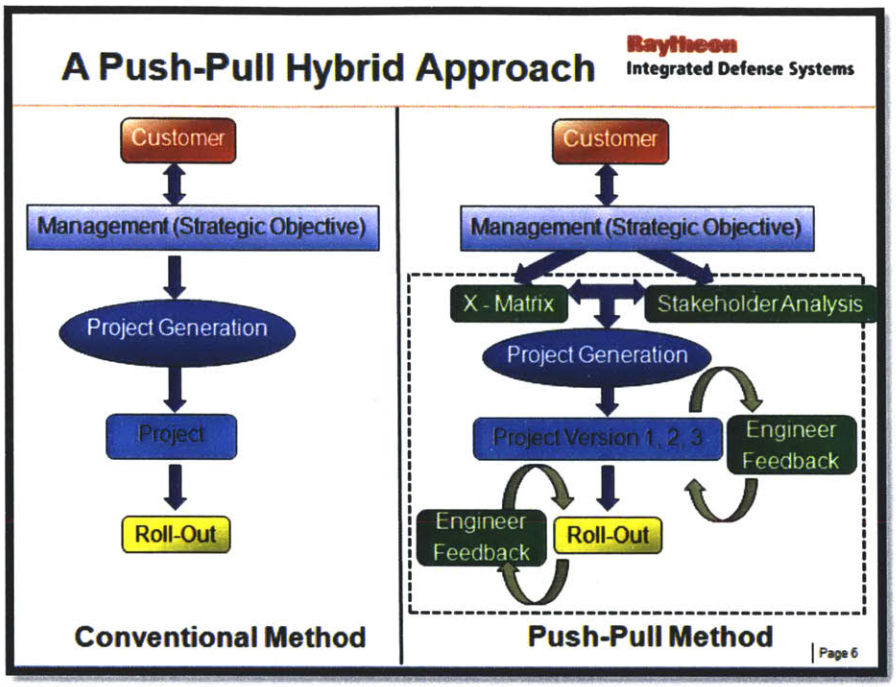


Figure 2: Push-Pull Hybrid Approach

Traditionally, the customer (either external as the military or internal as some other group inside Raytheon), explains requirements to management. Often, Raytheon must also communicate what capabilities it can offer, especially when the customer does not know/understand what its requirements are. Then management takes these findings and requirements and develops strategic objectives to meet these needs. A project is then generated to meet these objectives, executed, and rolled-out to the masses to be replicated throughout the facility. This traditional approach elicits very little feedback from the users and is generally termed as the Push Approach.

Conversely, as shown in Figure 2 on the right, is an alternative approach: The Push-Pull Hybrid Approach. The interactions between the customer and management remain the same. The strategic objectives developed by management are still paramount. However, this approach heavily relies on eliciting feedback and engagement from the user level. The idea is to fuse the strategic objectives from management with what is ultimately important to the user in order to generate a project or initiative that is important to both sides. To help bridge the gap(s) between management and user, some tools can be utilized (shown in green) and generate engagement and change momentum. These tools will be explained in greater detail in later sections.

Research shows that there are five strategic principles that are the foundation of total quality management:

(1) customer focus- both external and internal/other stakeholders [9]

(2) process focus

(3) teamwork- how much decision making or share to give away, which helps teams function with more ownership, where learning is internalized [9]. Teamwork entails the collaborative nature between managers and non-managers, across functions, and between organizations and their suppliers [11].

(4) employee participation- engagement and involvement go beyond simply asking for employee suggestions and feedback. It entails the delegation of authority to make decisions, pursue ideas, work with others to solve problems, and improve work systems [12].

(5) continuous improvement [13]

This implies that there is an implicit link or interface between quality control and continuous quality improvement [14]. See Figure 3 below:

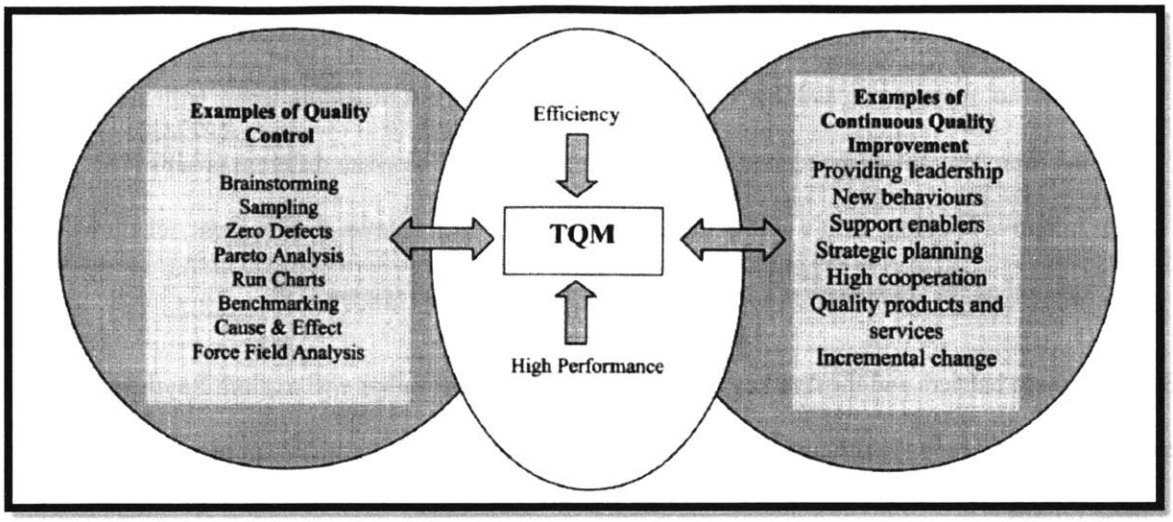


Figure 3: Integration of Quality Control and Continuous Quality Improvement

Here the reader can see that for TQM to work, it requires an integration of quality control and continuous quality improvement. Companies try to emulate the TQM model. However, in some cases they employ the quality control tools, without the strong backing of continuous quality improvement principles. Quality controls include Six-Sigma tools and analysis, of which Raytheon has plenty. Continuous quality improvement, on the other hand, is characterized by the five strategic components shown above. Raytheon IDS spends much more time and resources on quality control measures than it does on continuous quality improvement.

Contextual barriers such as strategy, decentralization, culture, and environmental adaptability pose challenges to the TQM process [15].

(1) Organizational cultures- organizations develop norms and ideologies by preserving certain behaviors and mental models [16]. In this sense, individuals may become prisoners of the systems and the bureaucratic structure of the organization may oppress learning.

(2) Organizations learning capacity- "Learning influences strategy by providing a boundary to decision making and a context for the perception and interpretation of the environment" [17]

(3) Decentralization- mistakes associated with rewarding and recognizing individuals instead of the team, not maintaining stability of membership over time, not providing teams with autonomy, and not espousing interdependence among team members and between different groups [18].

(4) Adaptive learning- firm's ability to align its activities with its own environment, which will depend on the organization's potential to learn, unlearn, and relearn [19].

Based on these barriers and the five key components of TQM, the author will explore Raytheon's current condition and will help the product development group undertake an alternative approach to avoid some of these pitfalls.

Raytheon observed that management typically turns-over every several years. With this turnover, priorities change and new initiatives are introduced. When new initiatives are introduced, quite often, the existing ones fall aside and the change initiative becomes what many term as "the flavor of the month". By using the Push-Pull Hybrid approach, despite management turns-over, the self-generating and self-sustaining momentum created from the user level should be enough to continue an initiative that is important to both management and user, as already shown in Figure 2.

Due to some of these pitfalls/obstacles to TQM, Raytheon's Product Development Group decided to take a different approach, one which would create change traction and self-sustaining momentum. The approach taken is outlined below and will be discussed in greater detail in the following sections:

1. Choose the "right" project
2. Choose the "right" group to pilot the approach and project
3. Engage leaders
4. Engage other stakeholders
5. Look at organizational architecture

These are some general steps we took, but should not be taken as a step-wise approach. Rather, the approach was very cyclical, where these different steps were repeated and even simultaneously

conducted. The intent here is *"Contrary to popular belief, people don't resist changes, they resist being controlled. And, the corollary to that is people who plan the battle, rarely battle the plan."*[8]

4 Choosing the "Right Project"

Choosing the "right project" required a couple of steps: 1) Understand the Organization: A Three Lens Analysis 2) Understanding the stakeholder values 3) Rank order projects. Choosing the right project was critical in creating traction and in self-sustaining momentum, despite the natural management turn-over.

4.1 Understanding the Organization: A Three Lens Analysis

STRATEGIC DESIGN:

As a part of the project, an X-Matrix analysis was used to identify any gaps or opportunities to improve from a strategic or organizational architectural perspective [20]. The four components of the X-matrix are: Strategic Objectives, Metrics, Key Processes, and Stakeholder Values (discussed in more detail in a later chapter). After this X-Matrix analysis was conducted, Raytheon realized that there was a misalignment of goals and objectives. Thus, Raytheon's management in the product development group also worked with MIT resources to develop a vision statement for the two pilot projects, which provided a stronger sense of purpose and direction.

Raytheon's Vision for Continuous Improvement: To create an environment where continuous improvement is adopted in order to increase speed and quality to meet mission assurance requirements for our internal/external customers.

This can be done specifically by:

1. Decreasing the number of audit findings
2. Increasing the efficiency in the labs
3. Protecting the products and those who work on them

Strategic Objectives:

After research and interviews of the product development group management, the strategic objectives were communicated to the users (engineers). Due to proprietary reasons, these cannot be disclosed.

Metrics:

By observing the metrics of the engineering group, the performance metrics are listed below (specific numbers are not used due to proprietary reasons:

- Provide on-time deliverable average of X%
- Strengthen interdependent execution- establish interdependent relationships with customers and teammates
- Meet Direct Labor Requirement ($X), achieve O/H rate
- Support safety related initiatives at all Missions Centers
- Achieve Reportable Injury Rate of X and Lost Work Injury Rate of X
- Support Security, and other mission critical audits, as per management
- Continue to drive process improvement and ensure obsolete processes are retired, inefficient processes improved and drive more process commonality
- Continue to work with Quality, Ops, etc to create common effective processes

Stakeholder Values:

Numerous stakeholder interviews were conducted. We defined stakeholders as any group or individuals that affects the product development group, which in this case were the engineers, managers, logistics team, material handlers, quality department, the Six-Sigma department, and the program management office. Below is a summary of the findings based on these stakeholder interviews.

- Want to have a say in improvement efforts within own areas
- Make the "lean" tools directly applicable to respective lab
- Have visibility of plan/schedule and requirements of testing
- Have the O/H to do continuous improvement. Also have the proper resources too
- Open dialogue with other departments (ie- auditors, programs, etc)
- Keeping clean and organized work areas
- Speed and quality

This is neatly summarized in Figure 4, which is a 2 x 2 matrix with relative stakeholder value along the horizontal axis and current performance (how well the enterprise delivers this value) on the vertical axis [21].

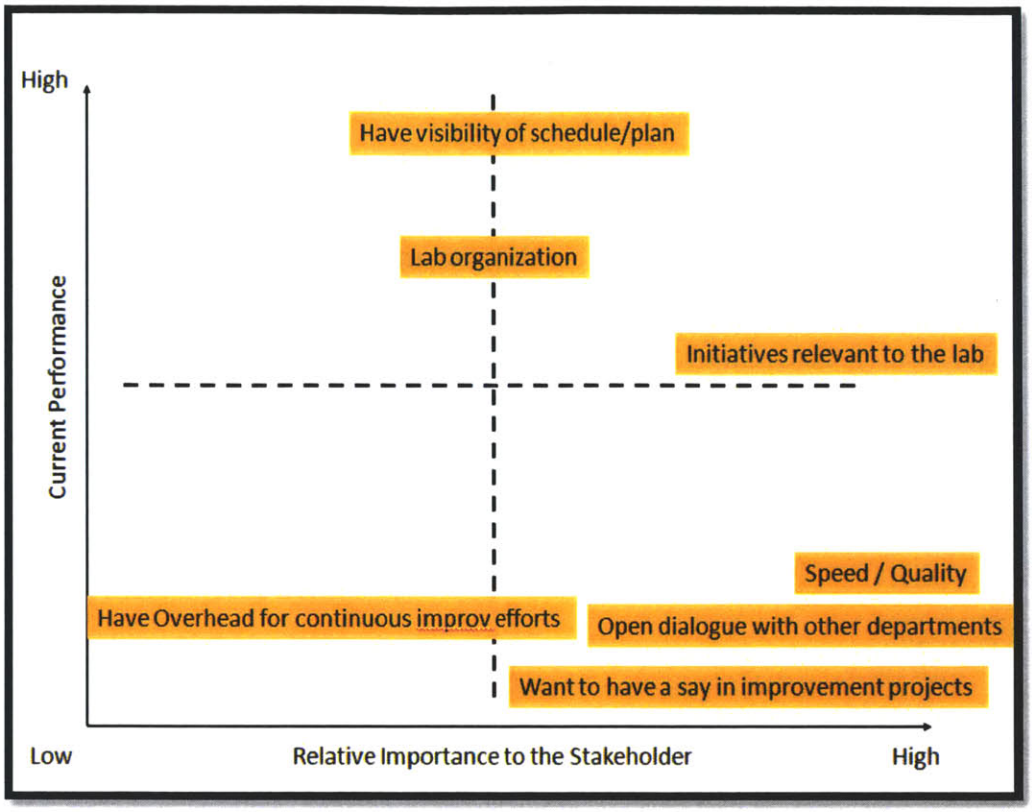


Figure 4: Stakeholder Importance vs Performance

The organizational structure of Raytheon is matrix in nature, which means that there are cross business teams (engineering, sourcing, etc) as well as integrated business teams (programs that include a team of 1 engineer, 1 sourcing personnel, 1 operations/manufacturing personnel, etc).

Figure 5 shows an example of an matrix organizational structure, the same structure that Raytheon emulates [22].

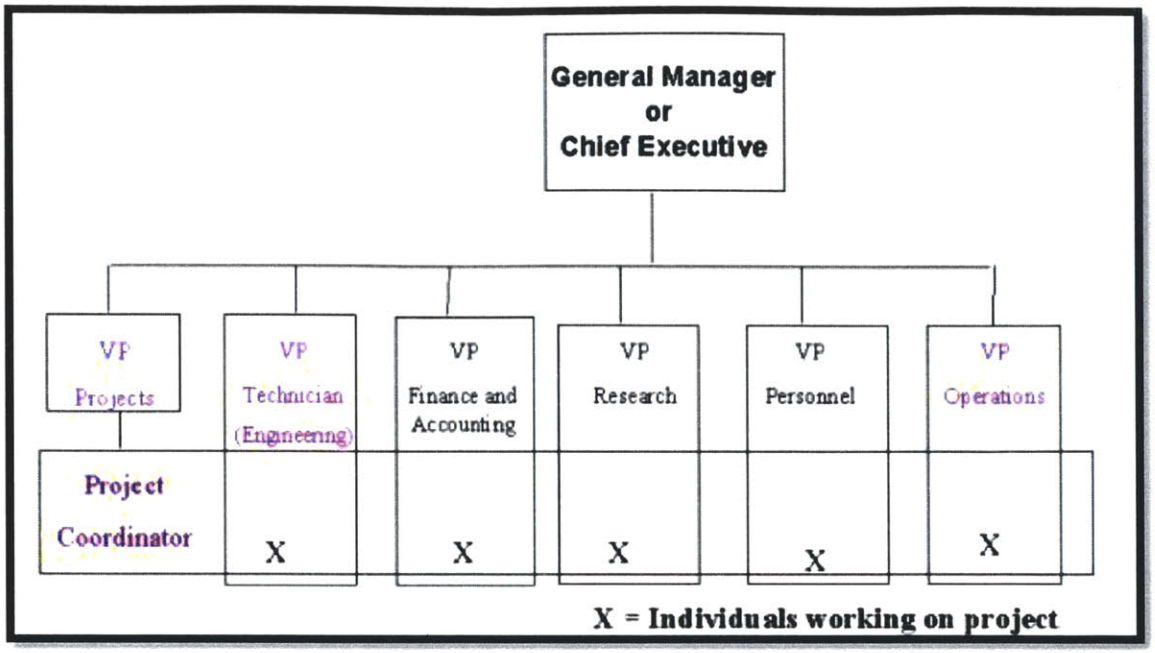


Figure 5: Example of a Matrix Organizational Chart

CULTURAL:

From a cultural perspective, Raytheon seems very focused on customer needs. In fact, littered on the hallway walls, are pictures of soldiers. In each facility, there are pictures of employees' relatives who are serving in the military, as well.

Culturally, because the primary customer is the military, Raytheon tends to operate similar to the military. It is a very top-down hierarchy. Furthermore, bureaucracy is rampant at Raytheon and to implement a new idea can take quite long for approval. This thesis/project will challenge the conventional bureaucratic process attempt to change the mindset of those in engineering.

Considerable time was spent in reaching out to management to garner buy-in, support, and engagement. Thus, the project is communicated and publicized through leadership, as well as through the user level networks.

The culture in the engineering and product development group is somewhat different. Many engineers tend to think that Lean only applies to the manufacturing shop floor. Thus, the term "continuous improvement" was used rather than "lean". Moreover, change to a process or "they way things have been done" is much harder to implement in the product development group than the manufacturing group because gains are not readily observed. Where eliminating waste may be visible instantly on the shop floor, it may take months or years (depending on the development cycle) to observe an improvement, and even then the improvement may not be perceived as attributable due to lean efforts. Thus, the nature of implementing lean in engineering typically is much more difficult and slower than it is in manufacturing.

POLITICAL:

Even though Raytheon has integrated business teams, we discovered that the organization is extremely "siloed" and the goals of one department may be diametrically opposed to that of another.

Through interactions, considerable push-back was experienced from the compliance group. Moreover, the program management (Aegis Program, Patriot Program, etc) seem to have the most power. For instance, the engineering test labs seem to be at the whim of program management. Thus, even when quality is the core competency of the test labs, because program management wants quick turn-arounds, the core competency becomes speed.

A stakeholder mapping exercise was conducted. The names of these individuals have been removed for confidentiality purposes. See Figure 6.

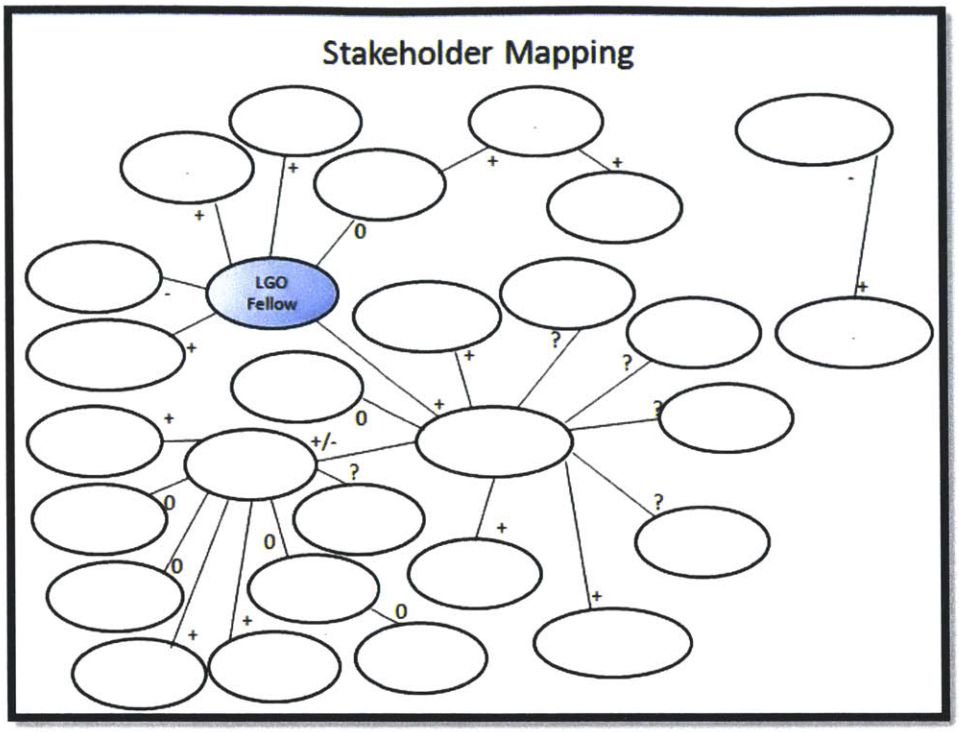


Figure 6: Stakeholder Mapping

The purpose of conducting the stakeholder mapping is to systematically understand those who advocate, allow, or may potentially block this project. The following symbols above have the following meanings:

Legend	
Symbol	**Meaning**
+	Supports initiative
-	Blocks initiative
0	Neutral
?	Not fully known

A project commitment chart was completed to depict current stakeholder commitment and desired future commitment. Stakeholder names are hidden for confidentiality purposes. See Figure 7 below:

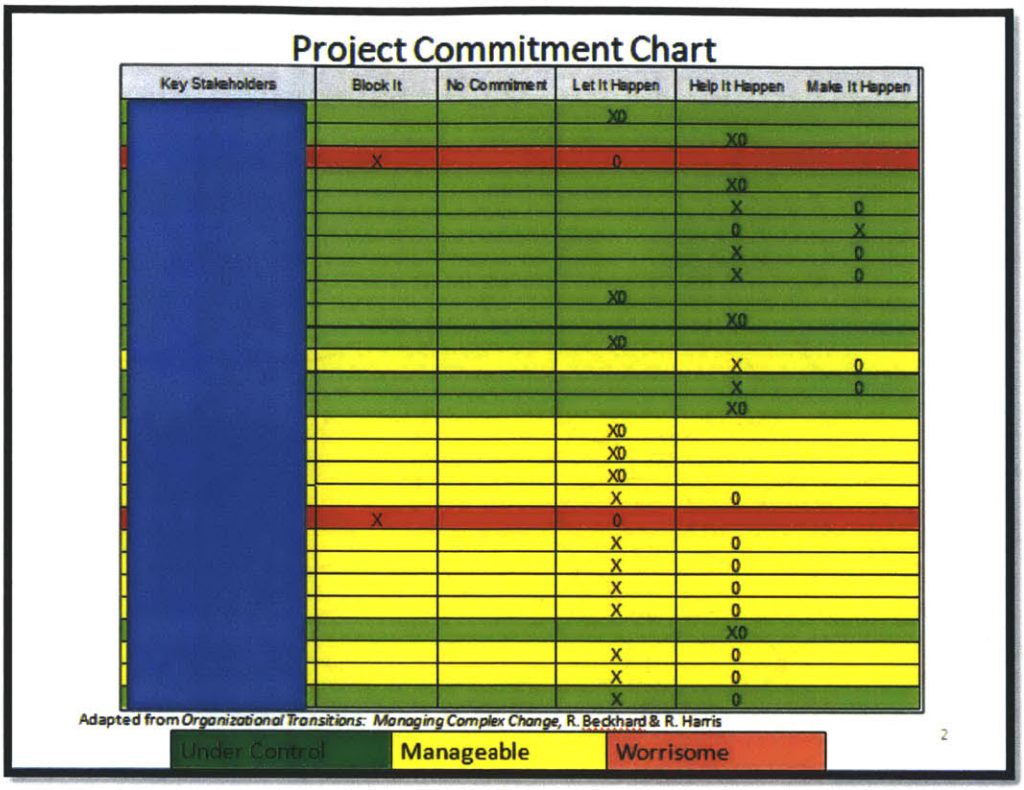


Figure 7: Project Commitment Chart

The "X" is current state and "0" is desired future state.

4.2 Personal Stakeholder Values

Research has shown that stakeholder values are extremely important, even to the point where they are even more important than organizational values (See Figure 8). Organizational values are those that Raytheon has written on its walls, the philosophy it embodies and expects its employees to internalize. According to a study, we see the relative importance between organizational and personal values. See Figure 8 below [23]:

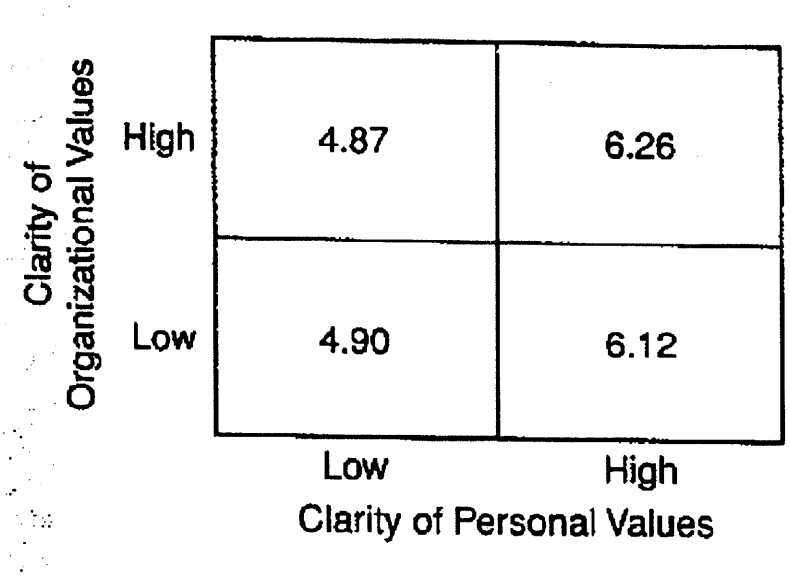


Figure 8: The Impact of Values Clarity on Commitment

This research suggests that values make a *significant* difference in the behavior at work. This figure outlines the clarity of organizational values (vertical axis) and the clarity of personal values (horizontal axis). These responses were correlated with the level of commitment from a person based on these factors using a commitment index 1 (low) to 7 (high). Those who have the greatest clarity about both personal and organizational values have the highest degree of commitment to the organization. Along with this research, we would expect those individuals who are unclear about their own and the organization's values to have only modest commitment and are more likely to be alienated from their work.

Surprisingly, the lowest level of commitment is in the upper left quadrant, where the clarity of organizational values are high and the clarity of personal values are low. The second highest level of commitment, however, is in the lower right quadrant, where the clarity of personal values is high and the clarity of organizational values is low. This suggests that people who know what they believe in but never have heard the corporate values are more likely to be committed to an organization than those who have heard the organizational credo but have never listened to their own inner voice. Consequently, personal values are much more significant to loyalty and commitment to an organization [24].

It was extremely important to understand the personal values of the stakeholders for some key reasons:

1. Allowed changed agents to understand what is significant and important to the stakeholder.
2. Gave the opportunity to individual stakeholders to think about their personal values and how it relates to work, leading to the process of clarifying one's personal values.

This became the fire-power to drive a continuous improvement lean initiative, one which was based significantly on the values that drive commitment from an individual. Again, finding and identifying with what is the most powerful source of commitment: one's own individual values and how that translates to workplace commitment.

Thus, Raytheon took a more formal approach to stakeholder interviews to more fully and clearly understand its stakeholder values and what impact those may have on a change initiative. See Figure 9 below and the questions that were asked during these stakeholder interviews.

Stakeholder Name: John Doe

Stakeholder Value	Issue	Importance Rating	Current Rating	Desired Rating

Figure 9: Stakeholder Interview Template

1. What are some things that you value as part of your job?
2. What value do you bring to the enterprise?
3. What value does the enterprise bring to you?

4. What are some things that work well to accomplish your job?
5. What limits you from doing better in your job today from a cost, speed, quality, or performance aspect?
6. What are some things that can help you do your job faster?
7. How much time is invested in the "people" aspect during change initiatives?
8. Why, in your opinion have past initiatives / projects not been sustainable?
9. How do you propose this can be done better (from previous question)?
10. What in your opinion or perspective what can make future projects more sustainable?
11. What are some things that can be done to accelerate change?
12. Where are other opportunities to improve?

Based on these interviews, the following values began to surface. See Figure 10.

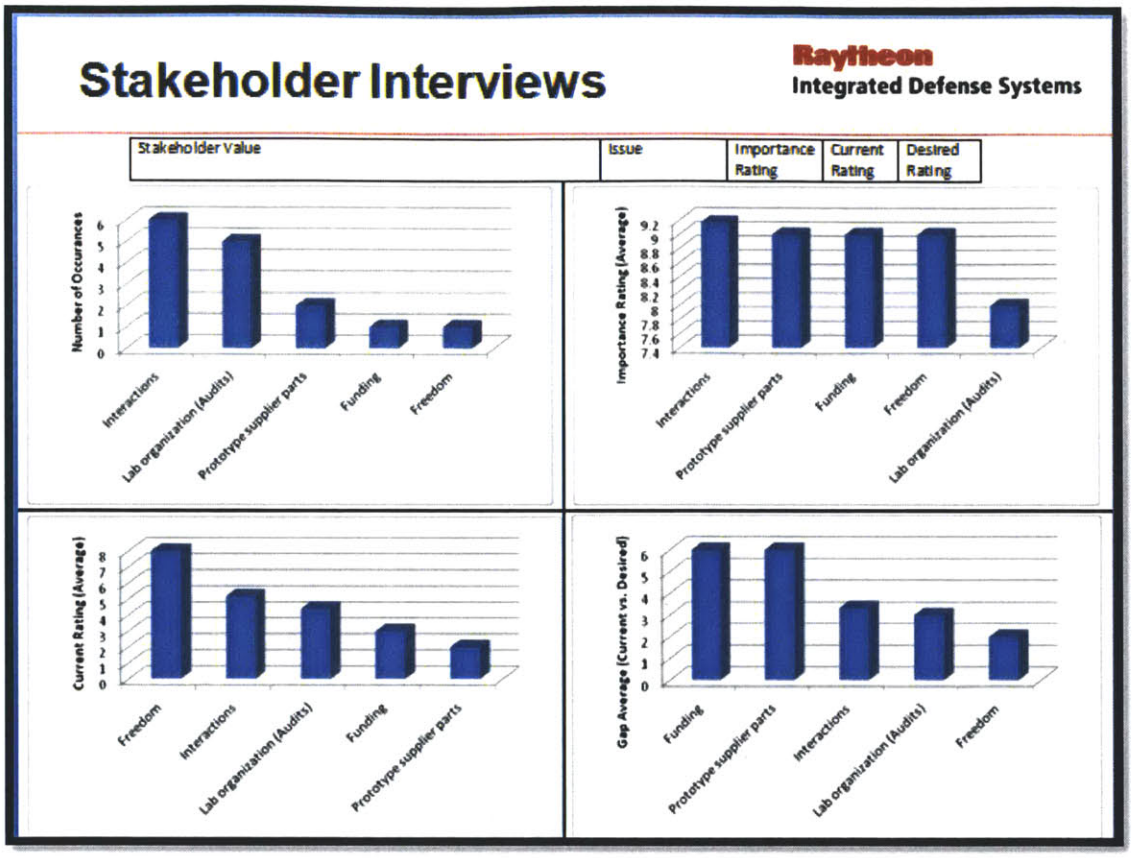


Figure 10: Stakeholder Interview Results

The upper left quadrant depicts the number of occurrences the stakeholder brought up as a pivotal issue. The upper right quadrant shows how important the issue is to his/her job or how limiting it makes his/her job (rated 1-10, as 10 denotes critically important). The bottom left quadrant shows the current rating of how that value/issue is performing (rated 1-10, as 10 denotes performing perfectly). The lower right quadrant shows the average gap between the current performance rating and the desired performance rating. A time horizon of two years was used to help the stakeholder gauge the desired performance rating. Thus, the stakeholder was asked, "Two years from now, what is your desired rating of this issue, operation, or value?" In this sense, the stakeholder would chose a desired rating that was realistic and attainable, rather than responding with a 10 rating for each value.

Based on these data, it was clearly evident that interactions between the different functional groups and the ability to affect 5S issues in the lab were the most critical and passionate issues that led to addressing the underlying values of stakeholders. Consequently, these projects also aligned with management's strategic objective to again:

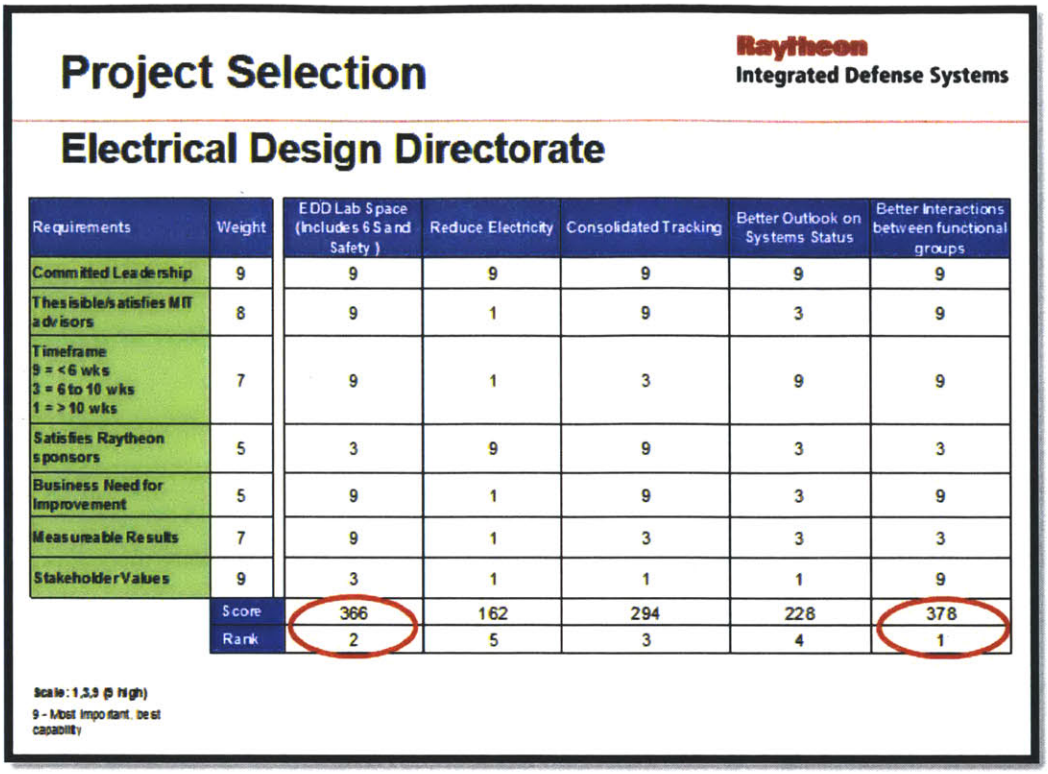
1. Decrease the number of audit findings
2. Increase the efficiency in the labs
3. Protect the product and those who work on them

It was clear, if Raytheon wanted to infuse a project that is important to both stakeholder values and strategic objectives, that pilot projects addressing interactions and 5S in the lab were most appropriate. The intent and approach are to conduct projects that are important and relevant to both stakeholders and management so that the lean change initiative is not short-lived and self-sustaining momentum could be maintained, even after management turnover.

Through this process, multiple stakeholders started to become more interested in these pilot projects because stakeholder values were sought and addressed. This initial engagement from the different stakeholders proved very useful in gaining further traction later on in the projects' execution phase.

4.3 Use Information Gathered to Choose the "Right" Project

Raytheon used a QFD (Quality Function Deployment) matrix to systematically determine which pilot projects to pursue. There seem to be some unintended and unforeseen consequences to using this tool as well. This tool helped communicate to the stakeholders that his/her input was considered but was not chosen due to other reasons [25]. Consequently, this tool helped communicate that the stakeholder feedback and interviews were important and considered and help manage the perception that stakeholder values are helping drive these pilot projects. See Figure 11 for the QFD performed to designate and prioritize pilot projects.



Project Selection

Raytheon
Integrated Defense Systems

Electrical Design Directorate

Requirements	Weight	EDD Lab Space (Includes 6 S and Safety)	Reduce Electricity	Consolidated Tracking	Better Outlook on Systems Status	Better Interactions between functional groups
Committed Leadership	9	9	9	9	9	9
Thesisible/satisfies MIT advisors	8	9	1	9	3	9
Timeframe 9 = < 6 wks 3 = 6 to 10 wks 1 = > 10 wks	7	9	1	3	9	9
Satisfies Raytheon sponsors	5	3	9	9	3	3
Business Need for Improvement	5	9	1	9	3	9
Measureable Results	7	9	1	3	3	3
Stakeholder Values	9	3	1	1	1	9
Score		366	162	294	228	378
Rank		2	5	3	4	1

Scale: 1,3,9 (9 High)
9 - Most important, best capability

Figure 11: QFD Matrix

This QFD matrix shows important requirements or criteria on the left side. Each requirement or criteria is weighted from 1-10 (10 being a critically important criteria). Note that the criteria of "Committed Leadership" and "Stakeholder Values" were weighted heavily in selecting a pilot project. Along the top, each project was noted and rated in terms of how well it would satisfy the listed criteria. The score was generated by taking a sum:product (multiplying the criteria importance weight by the project rating and adding these products). For the project ratings, a rating scheme of 1, 3, 9 was used. The purpose of this was to help delineate a desirable rating from those that were undesirable or less desirable and to give more weight to the desired ratings.

5 Choosing the "Right" Group

A social network analysis was conducted to help determine which group would have the best potential in spreading this change effort, pending its success. The idea was to treat this change effort like a virus, one which spreads throughout the organization. Raytheon just needed to find the right "host" to help contaminate the other groups [26].

Raytheon's current approach was to try to enforce change and have it spread to all the different groups at the same time. However, research shows that this effort can be hard to manage. Imagine trying to affect change among a hundred groups spanning thousands of individuals. One can imagine how challenging it would be to address all those concerns and manage expectations. Change is most effective when it is extremely targeted. So rather than attempting to engage every person in every group, target the most influential group/person and allow this effort to spread through this entity. Obviously, this has some tradeoffs. On one hand, it is very effective in the long run. However, it has the "S-curve" characteristic, whereby initially, the traction is very low and progress is slow. As the traction increases, the change effort gains momentum and exponentially increases. In the end, it tapers off due to saturation. See Figure 12 below:

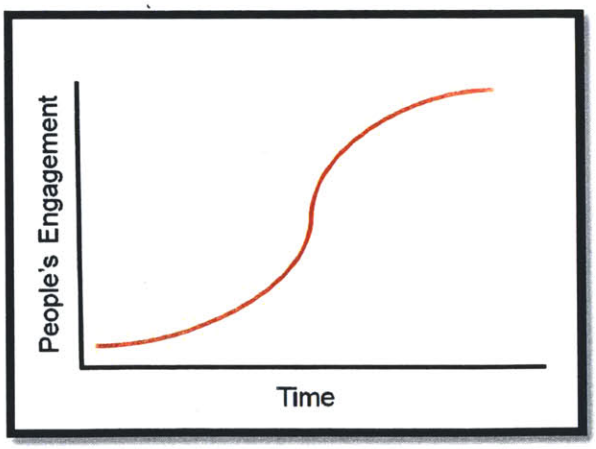


Figure 12: Relationship Between Time and Engagement

The research on social network analysis was extremely complex for the average person to understand. It entailed statistical analysis and algorithmic principles [30]. Raytheon wanted a social network tool that was easy to understand and implement, while still satisfying the intended purpose: to help identify the most influential group. Thus, an example of a modified social network tool was used below in Figure 13.

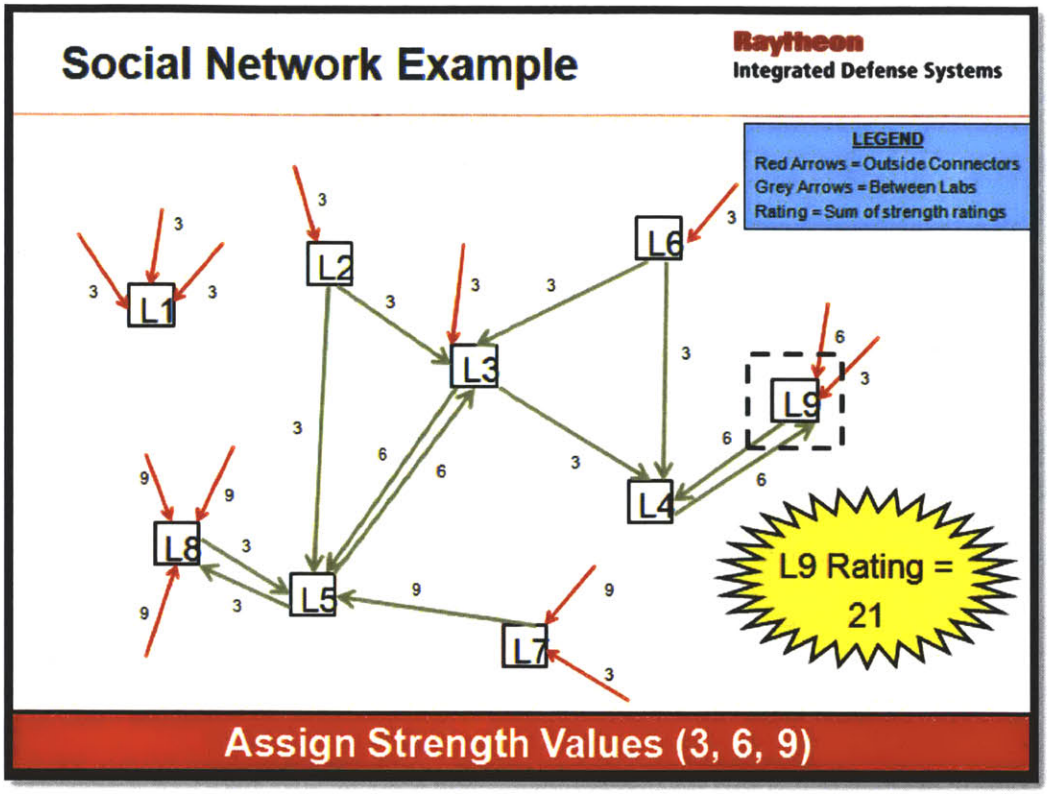


Figure 13: Social Network Analysis Example

For simplicity purposes, the L1, L2, etc stand for labs. The gray arrows represent the interactions between labs. The red arrows represent the interactions of the different programs and groups that feed into the labs. The number of interactions is important. However, quality of these social interactions needs to be accounted for as well. Thus, each interaction is rated with a 3, 6, 9 rating (9 rating having the strongest/healthiest interaction).

Throughout the course of this thesis, a paramount concept will be referenced: "Those who plan the battle, rarely battle the plan." Thus, during this exercise, numerous stakeholders and lab coordinators (those who are in charge of the respective labs), participated in this effort. The nature of the session was very collaborative and spurred engagement from the stakeholders. First the stakeholders defined what an interaction entails. These definitions/criteria of interactions are below:

- Number of meetings in a given week
- Length of each meeting
- Having lunch with one from another lab or program
- Outside of work, social interactions (baseball games, barbeques, skiing, etc).
- Number of times the program interacts with the lab (besides meetings)

Each arrow was drawn and then the interactions rated according to the quality of the interactions. Each location had a series of arrows flowing into it with assigned interaction strengths. By adding the strengths of all the interactions, the group was able to get a rough estimate of which lab to engage first in this effort to introduce lean in the product development group. This process was extremely collaborative and engaged the stakeholders, as they started to see the value of their own suggestions and expertise leading to an effort that was perceived as worthwhile, even when no hard data of concrete improvement existed yet.

Below is a picture of the actual social network analysis conducted with some stakeholders. Based on the analysis conducted, the group that had the biggest potential to affect change in the product development group was the Electrical Design Directorate Lab in Sudbury, MA. See Figure 14 below.

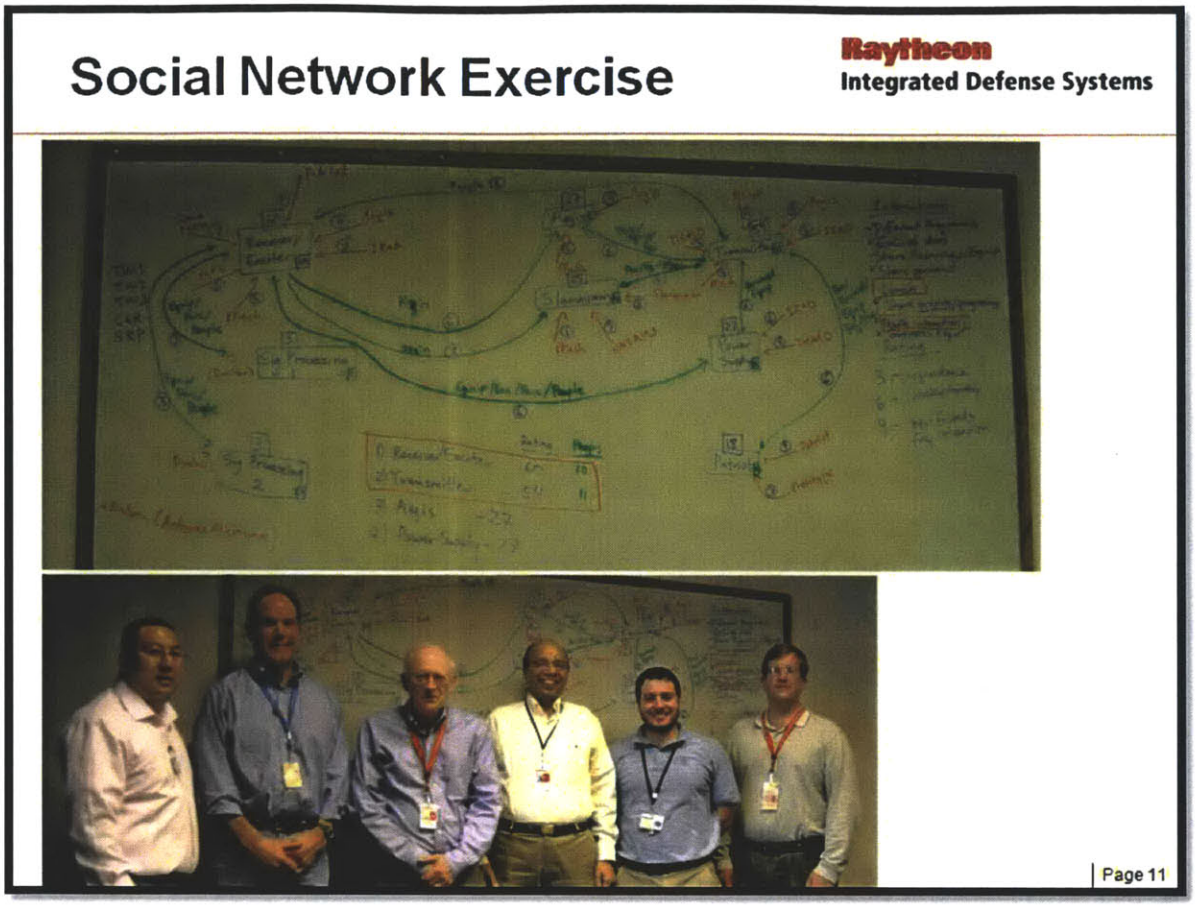


Figure 14: Social Network Analysis Exercise

6 Engage Leaders

Working with and engaging Raytheon's leadership in product development required a clear understanding of the organizational architecture. Raytheon's management realized that continuous improvement via lean efforts was necessary. However, over time, they have seen this same type of initiative fail but could not understand the reasons behind it. As Raytheon's product development leaders participated in delving into its current organizational structure and architecture, leaders began to realize that the organization's alignment may have hindered the ability or potential for true transformation to take place.

6.1 The X-Matrix

The X-Matrix was a primary tool used to engage leaders and to help them understand their organizational architecture. See Figure 13. The purpose of the X-Matrix is to identify the gaps in alignment between the quadrants. By strengthening these alignments, the organizational structure will help drive the appropriate behavior. Obviously, if continuous improvement is the behavior Raytheon wants employees to practice, the organizational architecture needs to be set up as such to drive that behavior.

The X-Matrix consists of four quadrants: Strategic Objectives, Metrics, Key Processes, and Stakeholder Values. As in Chapter 4.1, Raytheon identified what its current strategic objectives, metrics, and stakeholder values were. The key processes were discovered by engaging the Electrical Design Directorate Lab Coordinator. As shown in Figure 15, each cell is filled out with the corresponding quadrant. The interactions between the quadrants are what depict the strength of the alignment. For example, the interactions between the strategic objectives and metrics will show how strongly a particular strategic objective is measured by a certain objective. The shaded areas in blue note a strong alignment. Those cells shaded in yellow depict a weak alignment. Finally, cells with no color (white) are those with no alignment or interaction [31]. By engaging with Raytheon's product development leaders using the X-Matrix, it became clear that the organizational architecture had huge gaps and stronger alignment was

needed. See Figure 15 below (The strategic objectives and metrics have been disguised for proprietary reasons).

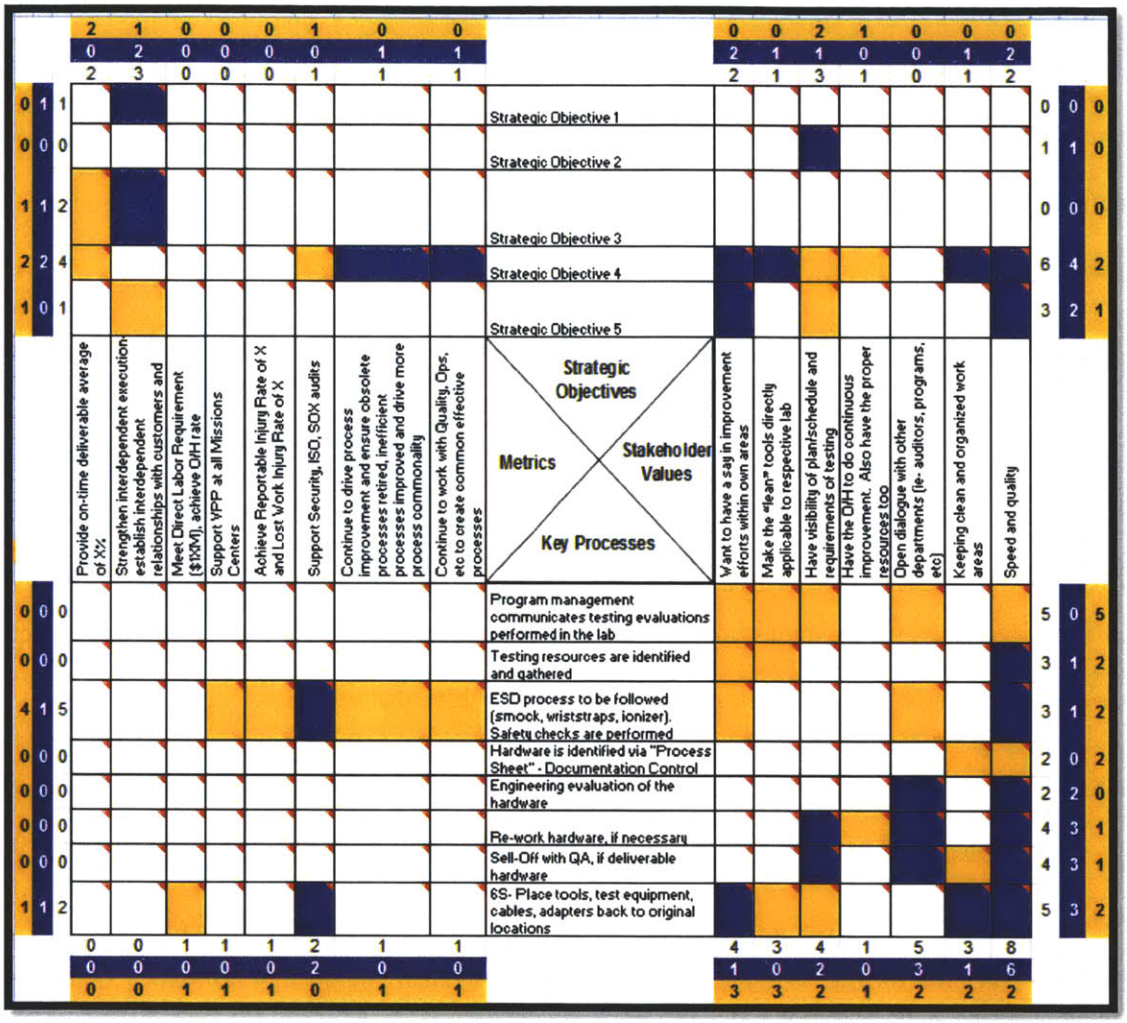


Figure 15: X-Matrix (Current Condition)

The following questions were asked to gauge the level of alignment between the various quadrants (It became quite important to ask these questions as written. These questions are structured so the independent variable feeds into the dependent variable. If not careful, quite frequently the dependent variable can feed into the independent one, which causes incorrect and inaccurate analysis of alignment):

- Is this strategic objective measured by this metric?

- Does this metric measure this process?
- Does this process contribute to the delivery of this stakeholder value?
- Is this stakeholder value represented by this strategic objective?

According to this analysis, it was evident that there were gaps in alignment between strategic objectives and metrics, metrics and key processes, and stakeholder values and strategic objectives. Raytheon's management understood that elements of the organizational architecture needed to change if strong alignment was to be achieved.

Based on the current condition X-Matrix some gaps or misalignments between strategic objectives and stakeholder values can be seen. See Figure 16 below:

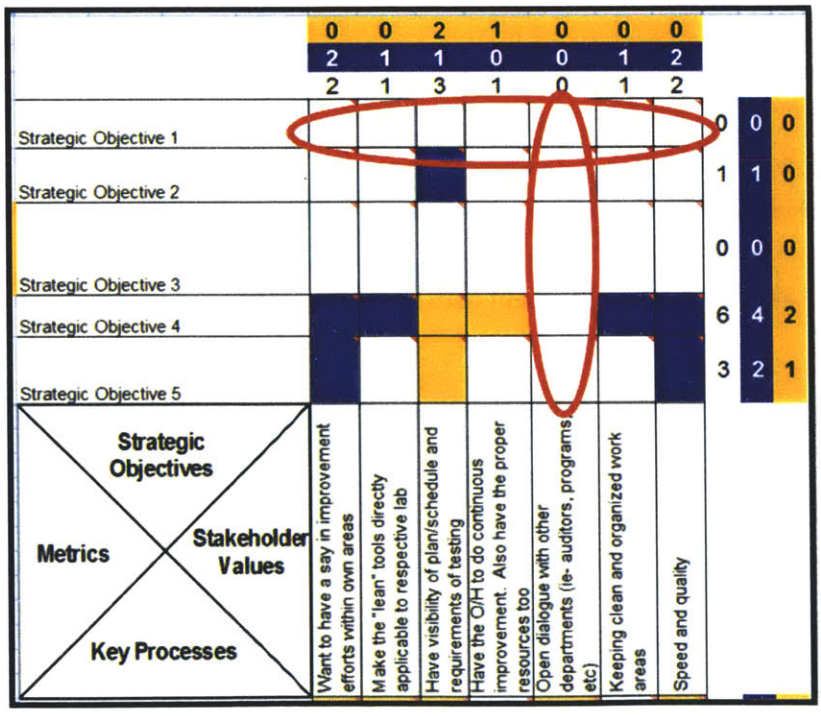


Figure 16: Mis-alignment of Stakeholder Values to Strategic Objectives

Specifically, the stakeholder value of open dialogue with other departments is not represented by any strategic objective. Furthermore, strategic objective 1 does not represent any stakeholder value.

Also, based on the current condition X-Matrix some gaps or misalignments between strategic objectives and metrics exist. See Figure 17 below:

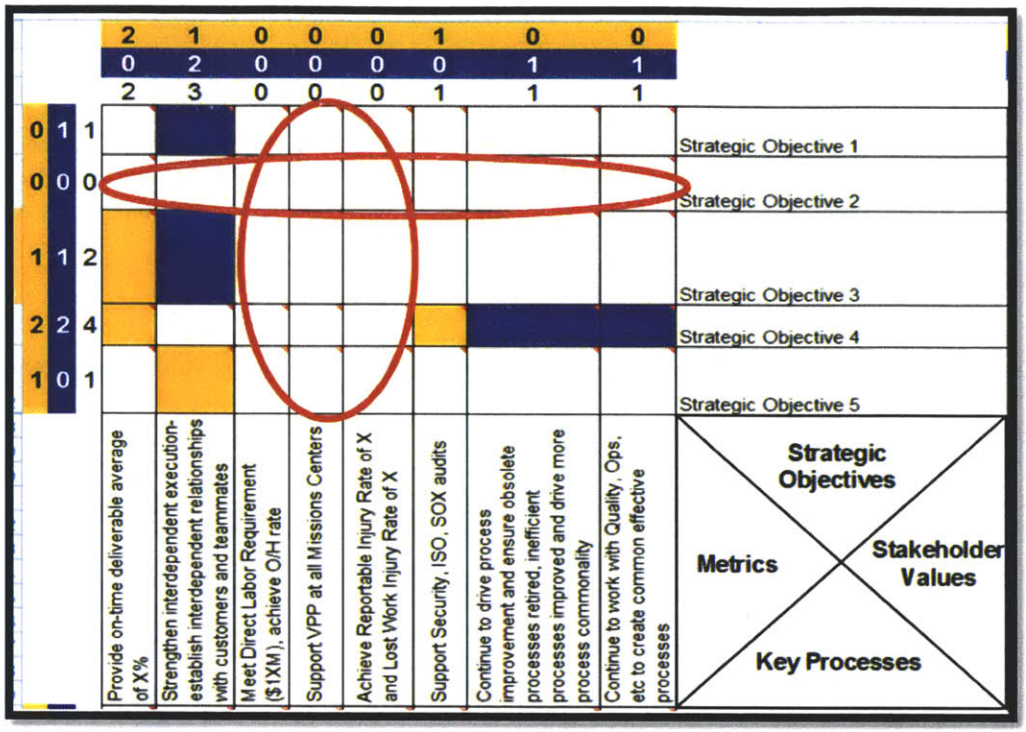


Figure 17: Mis-alignment between Strategic Objectives and Metrics

Here, the strategic objective 2 is not measured by any of the existing metrics. Also, there are several metrics that do not support any of the strategic objectives.

Given the data, there are also existing gaps between the metrics and key processes. For example, there are numerous processes that are not measured by any type of existing metrics. See Figure 18 below:

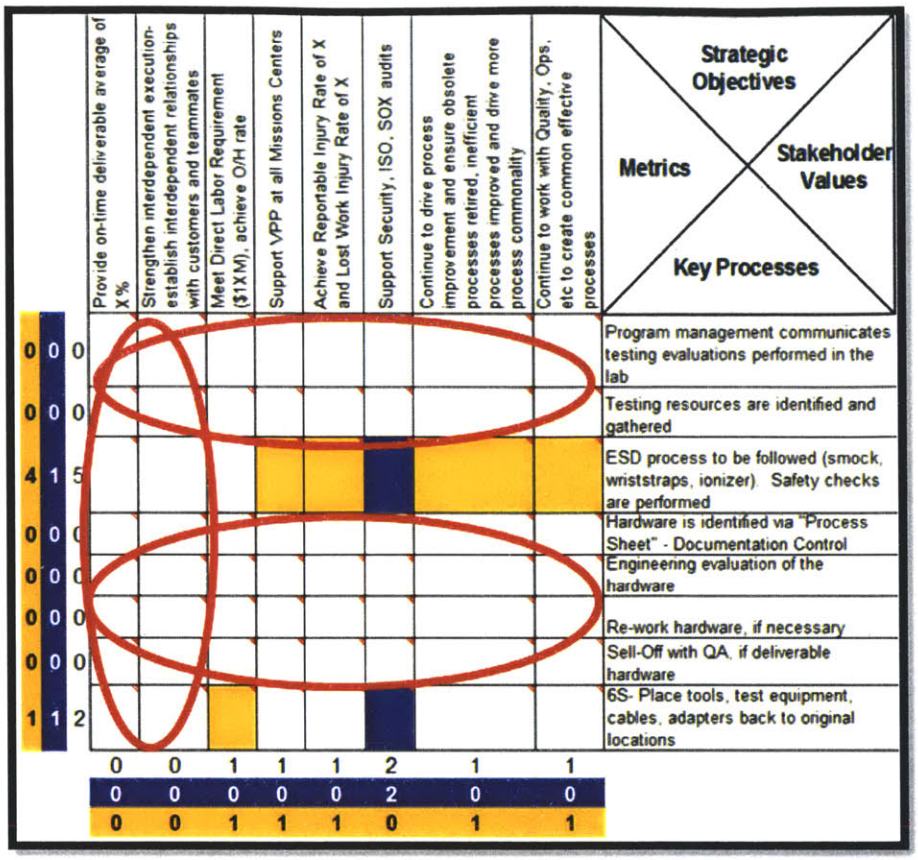


Figure 18: Mis-alignment between Metrics and Key Processes

Based on these mis-alignments, Raytheon took action to address these gaps and make the alignments more robust, as discussed in the next section.

6.2 Modification of Strategic Objectives

Raytheon's leaders modified the strategic objectives to make it more applicable to the product development group. The existing objectives were too broad and the engineers had a difficult time knowing the relevance of these objectives to what was done in their labs. Thus, the new strategic objectives for the labs in product development were developed (Not shown due to proprietary reasons):

6.3 Modification of Metrics

Management thought it necessary to also modify the metrics to help drive the appropriate change behavior. Also, the developing metrics resulted in a stronger alignment of having the strategic objectives being measured by these metrics and resulted in a stronger alignment of having the metrics measure the key processes. These are group metrics that measure the performance in each test lab. From a quantitative standpoint, Raytheon's product development group modified the metrics as the following:

- Efficiency

  1) Lab Overhead Labor vs Budget

  2) Lab Overhead Material vs Budget

  3) "Clutter reduction"- Square footage divided by the number of engineers and Before/After Pictures

- Effectiveness

  1) Number of findings per audit

  2) 6S Radar Chart

  3) Continuous improvement suggestions

- Capability

  1) Training Status (% certified: ESD, FOE, ESWP)

  2) Capital Equipment, Planning, and execution

- Capacity

  1) Lab Space Utilization - POA (better planning and measurement of actual utilization) - not sure how to measure this yet

2) Test Equipment Utilization – keep record of when equipment was used.

- Short term- manual paper sign-out and sign-in
- Long term- use of scanners and bar codes

- Behaviors Rating

  Raytheon discovered that to help drive positive transformation, individual behaviors should be measured. The purpose of these behavioral metrics is to help drive the appropriate personal behaviors. In the previous section above, Raytheon developed group metrics, but also needed to address individual metrics by measuring desired individual behaviors. Based on research, an aerospace company uses the following subjective measurements to gauge the behavior performance of its employees [33]. There are ten behaviors this company measures its employees by:

  1. Customer Focus
  2. Leadership Impact
  3. Credibility
  4. Makes People Better / Fosters Teamwork and Diversity
  5. Champions Change and Six-Sigma
  6. Intelligent Risk Taking
  7. Effective Communicator
  8. Self Awareness Learner
  9. Integrative Thinker
  10. Technical and Functional Excellence

Raytheon's performance measurement was based solely on results and did not rate its employees based on desired behaviors. Thus, this may espouse inappropriate behavior (ie- an employee doing everything he/she needs to do to meet a metric, even if it is deemed unethical or inappropriate behavior). Raytheon's product development leaders believed that a more integrative approach to performance rating should be a

combination of results as well as measurement of one's behavior. See Figure 19 below to view a one page revision to the performance report. Note what the following letters represent:

E = Exceeds Raytheon Standards

A = At Raytheon Standards

B = Below Raytheon Standards

D = Develop Further (Not necessarily a bad mark, but one that the manager stresses to the employee for further development)

Furthermore, in order to integrate results with behaviors, Raytheon could use the integrated 9 block rating scheme that Honeywell uses **Error! Reference source not found.**. See Figure 20.

Figure 19: One Page Performance Metrics

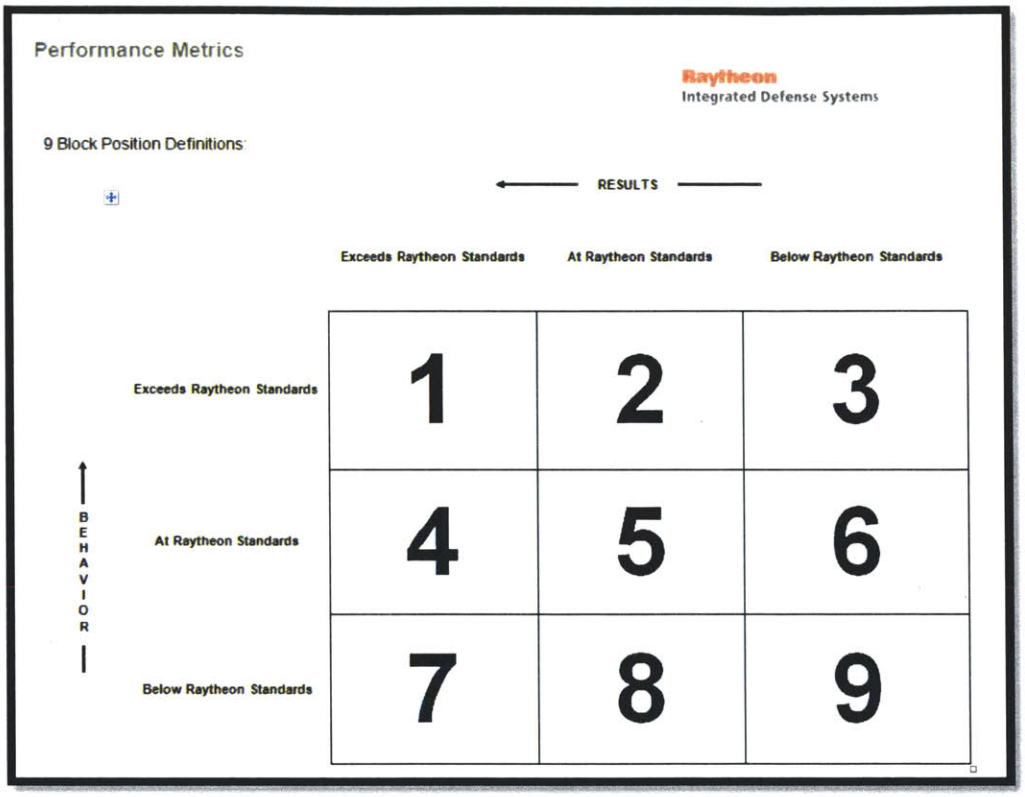


Figure 20: Nine Block Rating Scheme

Based on this 9 block rating, it incorporates both behaviors and results. On the horizontal axis, results are measured. As results based performance increases, the rating increases going from right to left. On the vertical axis, behaviors are measured. As the behavior based performance increases, the rating increases going from bottom to top. Consequently, those employees who fall in the 1 block rating exhibit both top behaviors and produce superior results. Most of the employees will fall in the 5 rating block. Those who fall in the "outer elbow" (ie, blocks 3, 6, 7, 8, 9 should be required to work with his/her manager to improve performance).

Obviously, the desired behaviors should be clearly defined to help rate this as objectively as possible. Below outlines the descriptions of what these desired behaviors are:

- **Growth and Customer Focus** recognizes that we need to think differently in order to grow. The customer is the cornerstone of our success. Effective employees do a superb job for customers every day in quality, delivery, value and technology. They aggressively pursue new opportunities through superior sales and marketing, globalization and technology roadmaps supported by Design for Six Sigma.

- **Leadership Impact** means thinking like a leader regardless of your job, delivering on commitments, and being a role model for others. All leaders demonstrate passion for their work and care about the people in the organization. You will be expected to be able to: [1] conceptualize an issue, [2] develop an action plan to address the issue, and [3] execute the plan.

- **Get Results** requires consistently meeting commitments to the business and to others. Quickly translate business requirements into actions by defining "who does what by when" to ensure plans are executed.

- **Makes People Better** encourages excellence in peers, subordinates and/or managers. Be a positive influence in the development of others

- **Champions Change** drives continuous improvement and fosters a continuous improvement mindset to make decisions that are in the best interest of customers, shareowners, and the organization. It reflects a constant commitment to do things better. Raytheon employees are expected to champion change that ensures the long-term strength of the company regardless of personal impact.

- **Fosters Teamwork and Diversity** defines success in terms of the whole team. Employees must understand and capitalize on the fact that Raytheon's workforce is composed of individuals who represent a great diversity of values, opinions, backgrounds, cultures and goals. Raytheon employees must recognize diversity as an important value and develop diverse teams. Effective team leaders not only meet the expectations of their role as leaders, but they also set and meet the expectations for team members.

- **Global Mindset** is viewing the business from all relevant perspectives and seeing the world in terms of integrated value chains.

- **Intelligent Risk Taking** recognizes that generating greater returns requires taking greater risks. While using sound business judgment, Raytheon employees must have the courage to take action where outcomes are uncertain but where potential rewards are great. Business decisions often need to be made based on incomplete information.

- **Self-Aware/Learner** individuals recognize their behaviors and how they affect those around them. Employees must accurately assess their own strengths and weaknesses and take action to improve.

- **Effective Communicator** means providing timely and concise information to others, and using clear and thoughtful oral and written communications to influence, negotiate and collaborate effectively. Leaders and employees need to appreciate that effective communication is about listening and being listened to but is not always about being in agreement.

- **Integrative Thinker** decides and takes actions by applying intuition, experience, and judgment to the data available. Raytheon employees must demonstrate the ability to assimilate various and conflicting information or opinions into a well-considered decision, and they must understand the implications of individual actions or recommendations on other systems, departments, processes and functions.

- **Technical or Functional Excellence** means being capable and effective in a particular area of expertise. Employees must remain aware of advances and current thinking in their fields and look for ways to apply the latest technologies to their work [34].

6.4 X-Matrix with Modifications

Based on Raytheon's modification of strategic objectives and metrics, it is clearly evident that there is stronger alignment with the four quadrants. See Figure 15 for Current Condition X-Matrix and see Figure 21 for Revised Condition X-Matrix below.

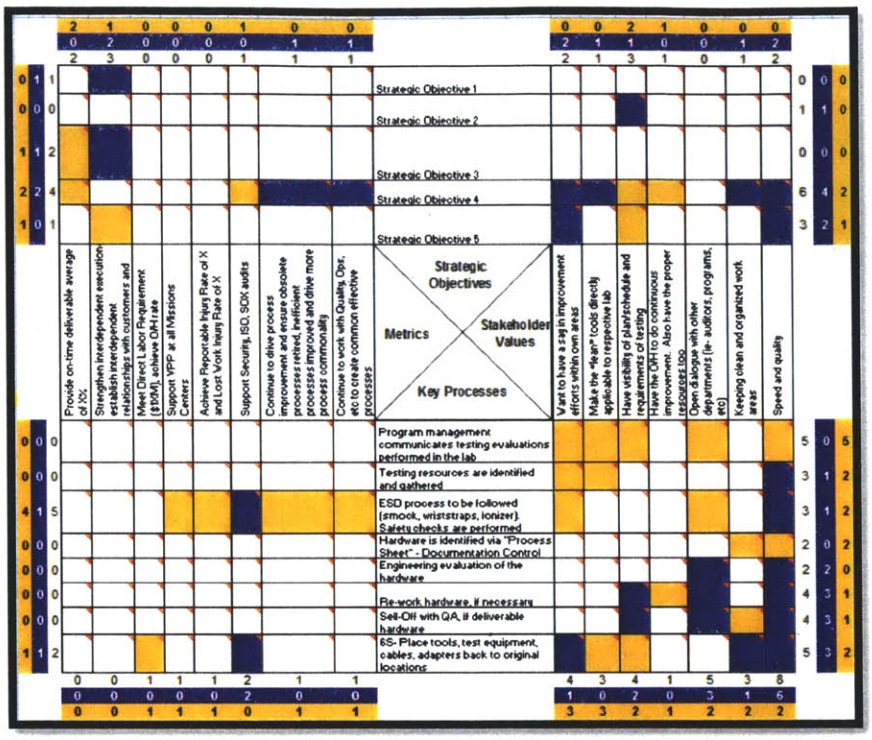


Figure 15: Current Condition X-Matrix

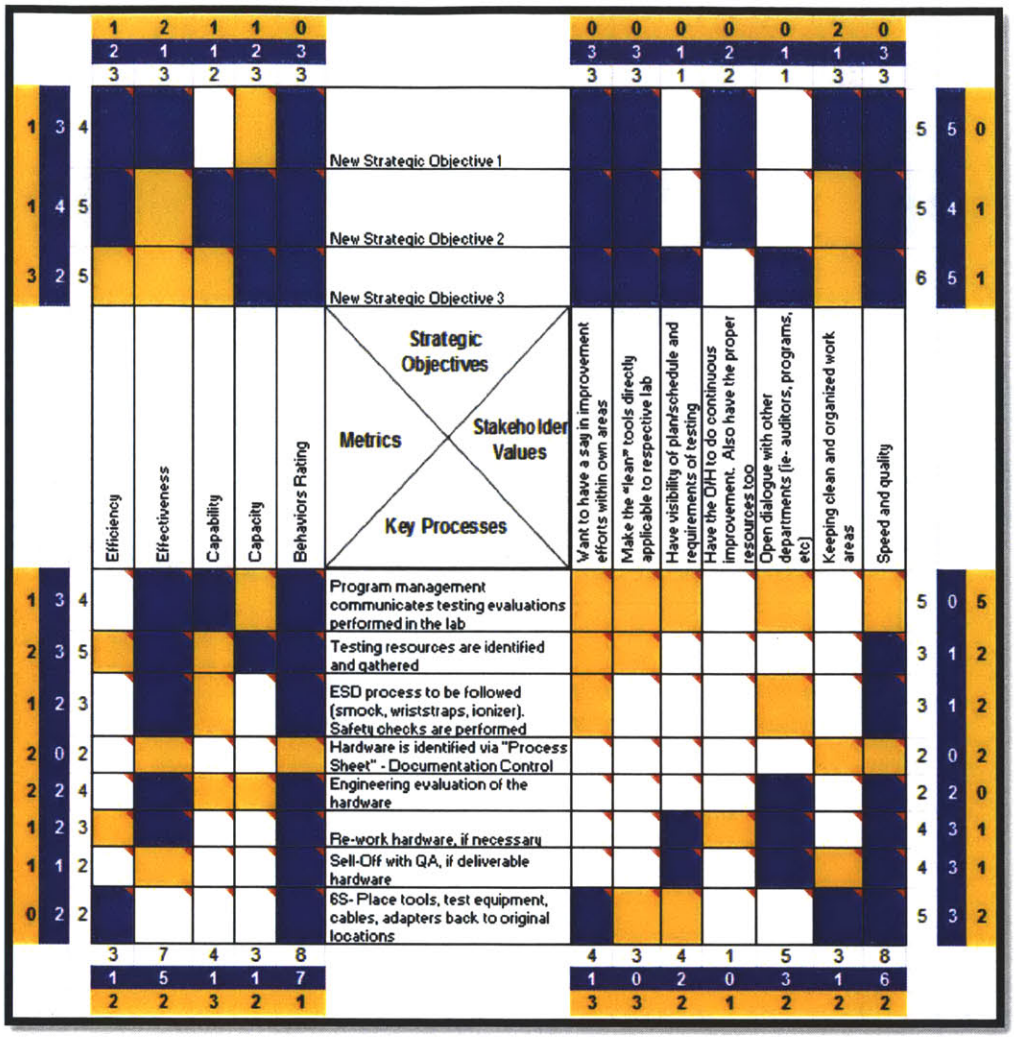


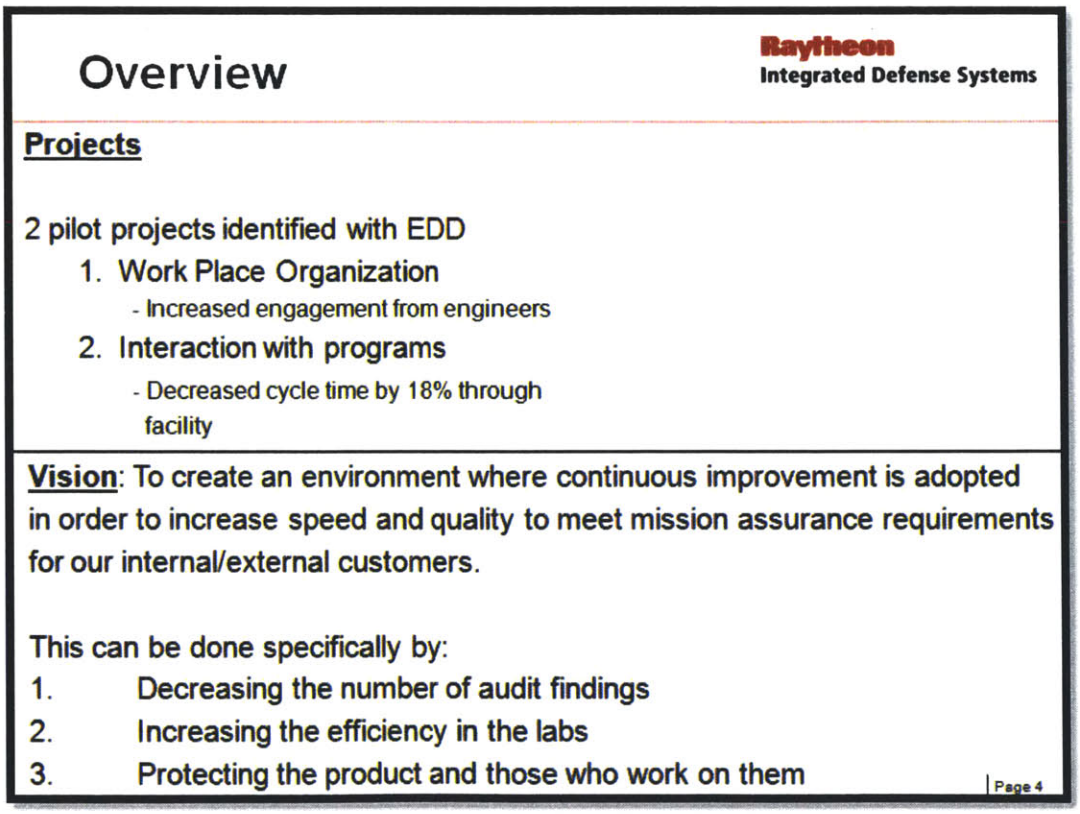
Figure 21: X-Matrix (Proposed Condition)

7 Keeping Stakeholders Engaged Through Project Execution

Previous chapters addressed really understanding stakeholder values, choosing the right project and group, understanding current conditions with reference to organizational architecture, and engaging leadership. Until now, there has not been much mentioning of execution of these chosen pilot projects. This chapter will focus on the 2 chosen pilot projects and will continually refer to the recurring theme: "Those who plan the battle, rarely battle the plan" [8].

7.1 Project Execution

Here's a summary of the 2 pilot projects:



Project 1:

Prior to each meeting or collaboration session, the vision and purpose was expressed. The first project dealt with the engineers having more of a voice when it came to workplace organization (5S) in their own labs. Based on stakeholder interviews, this quotation surfaced:

"The peanut butter spread approach doesn't work. You can't simply apply everything in one group and expect it to be applicable to the next. Things need to be modified so it applies to my group"

The engineers were given a 5S checklist that manufacturing at a different site used. Unfortunately, many elements in this checklist were not applicable to the engineering test labs. Furthermore, the engineers felt it necessary to add several items to make it more applicable in the lab. It was clearly evident that the checklist was one that was formulated for the manufacturing shop floor and management wanted it to be used for 5S in other areas. Thus, the engineers were given the opportunity to exercise their experience and modify this checklist. This checklist became a direct measurement for how the lab was rated for performance. The checklist below is the revised checklist that all lab coordinators now use:

Safety

1. PPE- Personal protection equipment in use when necessary
2. Ensure goggles or safety glasses are available in the lab
3. Aisles- Main aisles, emergency exits, and main entrances are clear (unimpeded movement) in the lab
4. Evacuation- Emergency exit signs are in place and visible
5. Emergency Equip- Fire extinguishers and eye wash stations are certified and easily identified and accessible.
6. Electrical- Electrical panels accessible and marked. Ensure electrical panels/areas are taped off with at least 36 inches of clearance.
    a. Machines/Equipment- Safety guards, interlocks, working and visible
7. High voltage test equipment has warning signs in place
8. Hazards- Chemical and safety hazards properly identified (with shelf life) and stored. MSDSs are available and accessible for all chemicals. Signage posted for MSDS information.
9. Ask to see if all lab personnel are trained/certified on Electrical/Safety Work Practices
10. Check to ensure that all required personnel have the Radio Frequency (EEEC) Training complete (if applicable if working with RF power, as per Section 4.2 of 000000038-RP)

Sort

1. A "Red Tag" disposition area exists and is clearly marked
2. Verify that all tools are returned to the proper place at the end of each shift
3. Tools (including hand tools) are stored separately and not co-mingled with material or product
4. Tools are in a serviceable condition
5. Personal items, food, or drinks in designated areas only. No plants (fake or live).

Shine

1. Items are not stored on the floor, on top of cabinets, material racks or equipment
2. Benches, floor, racks, equipment are clean and free of oil, dirt, dust, or debris at the end of each shift
3. Ensure $C0_2$ lines are not leaking or dripping
4. No paper or sticky notes allowed within 1 ft of ESD work benches unless ionizer is in use. (ie- No dangling, hanging of papers, calendars, labels, pictures, tags, etc)
5. No frayed signs or labels (not peeling). All signs are uniform.
6. All "drops" from agile grid are bundled and straight. All equipment cords are tied and off the floor and not obstructing aisles.
7. ESD foam and other protective medium is not torn, scratched, or shedding

Set in Place

1. Classified (if applicable) areas product/material media are clearly identifiable and properly secured
2. Product is clearly identified and marked as deliverable/non-deliverable
3. All areas are clearly identified as NON/ESD- all exceptions to workstations, equipment or storage are clearly/properly identified
4. Non conforming material is identified and segregated
5. All posted information is current and in designated areas
6. Cleaning materials (wipes, cleansers) are available, accessible, labeled and in their designated locations

Standardize

1. All lab personnel know where to access ESD, FOD, Security, OSHA standards
2. All personnel are ESD and FOE trained and adhering to those standards

Sustain

1. 6S checklists, radar charts, improvement plans are posted
2. Lab coordinators ensure 6S standards are maintained daily
3. The 6S score and improvement plan including FOD preventative actions are updated weekly and discussed at monthly lab coordinator meetings
4. Cleaning guidelines including facility checklist is updated, maintained, and posted
5. Lab coordinators ensure safety audits and training are performed by EHS personnel
6. Lab FOD criticality level known by all lab members and visitors and are prominently displayed
7. ESD protective equipment is worn, log books are filled out

This checklist is placed on an electronic portal known as VBS (Virtual Business System). Thus, it can be accessed by anyone on the team, as long as access is granted. Furthermore, the checklist can be filled out online and the results displayed on an LCD screen in the lab. To help further spur momentum in the EDD lab, Raytheon also developed a suggestion/feedback eliciting system, which is now a part of the VBS portal system. The capabilities of this system are described below:

- Ability to be filled online by anyone on the team
- Tracking system to note how long the suggestion has been sitting in queue to be answered
- Management required to respond to the suggestion (ie- assign owner and date or reject the suggestions with justifiable reasons) by a certain timeframe
- Suggestion spreadsheet visible on LCD board with real-time updates (this helps build pride and ownership among the engineers as their suggestions are presented on the screen and can note manager's comments).

An example of a screenshot of this VBS portal with 5S checklist is in Figure 22.

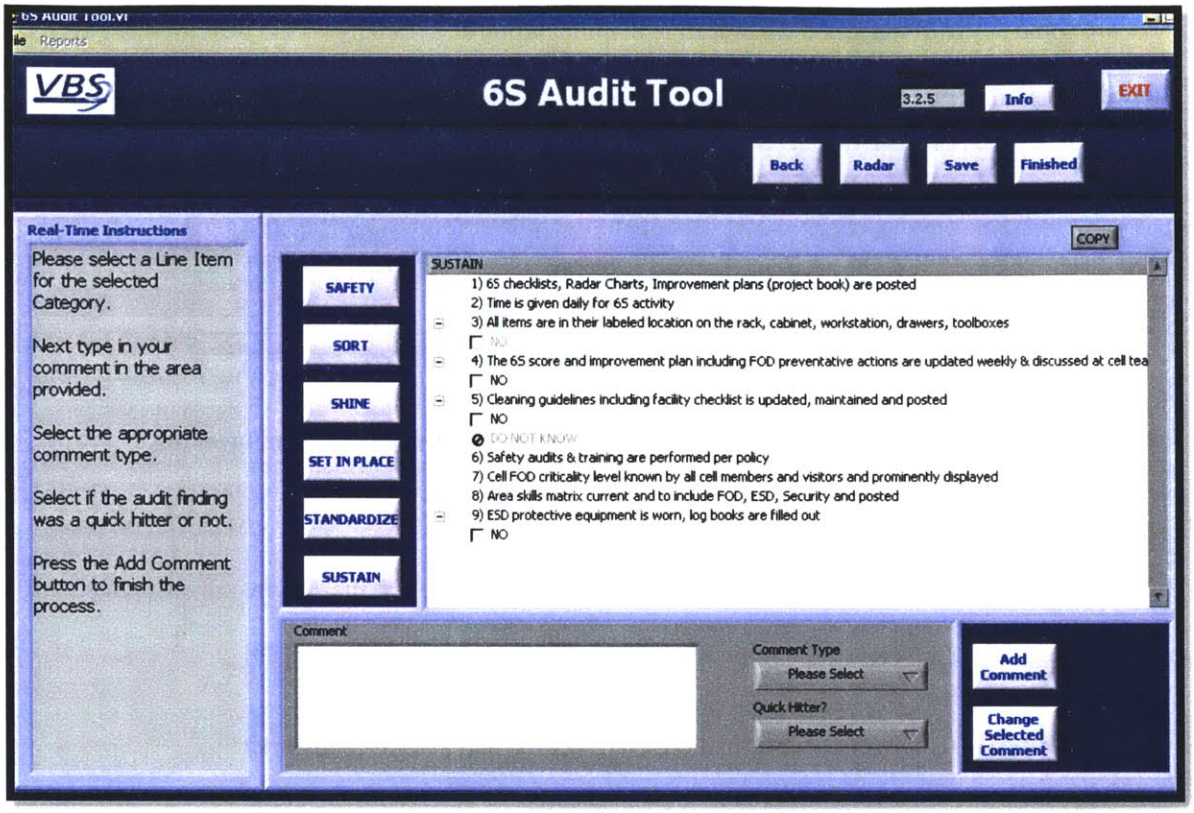


Figure 22: Screenshot of the 5S Checklist

The exercise of engaging the engineers to revise the 5S checklist as well as giving them the ability to freely offer suggestions and solutions to problems have greatly increased their desire to contribute to the change effort and implementing lean in the product development labs.

Project 2:

Project 2 addresses the primary concern expressed during many of the stakeholder interviews: The lack of interactions between the test labs and other functional groups (ie, logistics, program office/management, material handlers, quality assurance, etc). Note: stakeholders in these other functional groups were part of the stakeholder interview process.

There are some key differences between lean in manufacturing and lean in product development as outlined below in Figure 23 [32]:

	Manufacturing	Engineering
Value	Visible at each step, defined goal	Harder to see, emergent goals
Value Stream	Parts and material	Information and knowledge
Flow	Iterations are waste	Planned iterations must be efficient
Pull	Driven by takt time	Driven by needs of enterprise
Perfection	Process repeatable without errors	Process enables enterprise improvement

Figure 23: Differences Between Lean in Manufacturing and Engineering

The 7 forms of waste that people want to eliminate are below. However, the 7 forms of waste that exist in manufacturing take a different form in product development, as outlined below [27]:

- **Waiting**: Late delivery of information; Delivery too early (leads to rework)
- **Inventory**: Lack of control; Too much in information; Complicated retrieval; outdated, obsolete information
- **Over-Processing**: Unnecessary serial production; Excessive/custom formatting; too many iterations
- **Over-Production**: Creation of unnecessary data and information; Information over-dissemination; Pushing, not pulling, data
- **Transportation**: Information incompatibility; Software incompatibility; communications failure; Security issues
- **Unnecessary Movement**: Lack of direct access; "Walking" the process
- **Defective Products**: Haste; Lack of reviews, tests, verifications; Lack of interpretation (raw data delivered when information or knowledge needed)

A more detailed description of the wastes seen in product development is below in Figure 24 [28] :

Figure 24: Examples of Waste in Product Development

Types of Information Waste	Examples	Causes
Waiting *Idle time due to unavailable information*	People waiting for information	• Lack of access • Untimely updating of data bases • Multiple approvals • Poorly designed or executed process to provide information
	Information waiting for people	• Information created too soon may be obsolete by the time it is used
Inventory *Information that is unused or is "work in progress"*	Too much information	• Poor understanding of user needs
	Multiple/redundant sources	• Tendency for everybody to maintain their own files
	Outdated/obsolete information	• Lack of "version control" • Lack of disciplined system for updating new and purging old information • Inadequate archiving standards or practices
	"Just-in-case" information	• Collection, processing and storage of every element of data that process participants can think of, whether or not a specific end use has been identified
Excessive Processing *Information processing beyond requirements*	Excessive/custom formatting	• Lack of standardization
	Numerous, fragmented reports	• Poor output design • Lack of understanding of the needs of the users of process outputs
	Unnecessary serial processing	• Poor system design • Lack of understanding of concurrent processing capabilities
	Excessive approvals for information release	• Stove pipe, command and control mentality • Turf protection
Over Production *Producing, distributing more information than needed*	Unnecessary detail and accuracy	• Tendency to "over-design" • More detail than necessary in early design
	Pushing, not pulling data, information	• Uncontrolled process
	Over-dissemination	• Poor understanding of each participant's needs • "Send all information to everyone," rather than to meet specific needs

Types of Information Waste	Examples	Causes
Transportation *Unnecessary movement of information between people, organizations, or systems*	Information handled by multiple people before arriving at user	• Lack of direct access due to IT system limits, organizational inefficiencies, knowledge hoarding, security issues
	Information hunting	• Lack of clear information flow paths, failure of process to produce information needed
	Data re-formatting or reentry	• Incompatible information types (drawings *vs.* digital descriptions) • Incompatible software systems or tools • Lack of availability, knowledge, or training in conversion and linking systems
	Switching computers (e.g., CAD to PC) to access information	• Software/hardware incompatibilities • IS support
Unnecessary Motion *Unnecessary human movement (physical or user movement between tools or system)*	Walking to information, retrieving printed materials	• Lack of distributed, direct access • Lack of on-line access • Lack of digital versions of heritage information
	Excessive keyboard, mouse operations	• Lack of training • Poorly designed user interfaces • Incompatible software suites • Too much information to sort through
	Poor physical arrangement or organization	• Team members not co-located • Organization structure inhibits formation of right teams
Defects *Erroneous data, information, reports*	Errors in data reporting/entries	• Human error • Poorly designed input templates
	Errors in information provided to customers	• Lack of disciplined reviews, tests, verification
	Information does not make sense to user	• Raw data delivered when user needs derived information, recommendations, or decisions

By using the VSM (value stream mapping), Raytheon discovered that there was some significant waste that could be eliminated. Raytheon's product development group, however, took a less traditional approach to VSM. They looked primarily at how information flows from one group to another and the health of an interaction between functional groups, as opposed to a particular product. With this new approach, the stakeholders rated the health of the interaction between groups, especially during hand-offs of information. Similar to the ranking of interactions in the social network analysis, the stakeholders

together determined a way to measure the health of the interaction between groups during these information transfers. Again, the stakeholders *developed* what they deemed as a good way to rate these interactions, which is consistent with: "Those that plan the battle, rarely battle the plan" [8].

Furthermore, it is important to look at the enterprise from a holistic perspective for the following reasons [29]:

- Modern enterprises are highly interconnected systems
- Need to integrate management processes, lifecycle processes and enabling infrastructure systems
- Must balance needs of multiple stakeholders working within and across boundaries
- Lack of holistic thinking creates suboptimal enterprise

A screenshot of the VSM conducted is below in Figure 25.

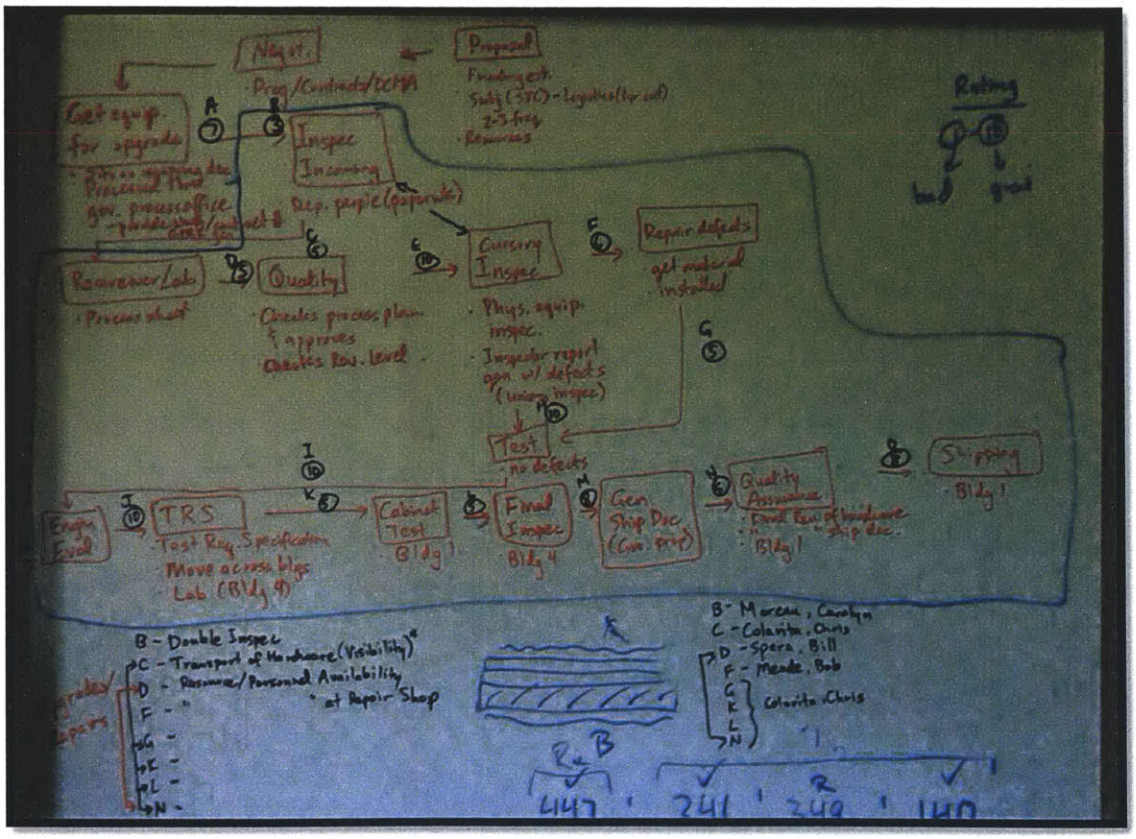
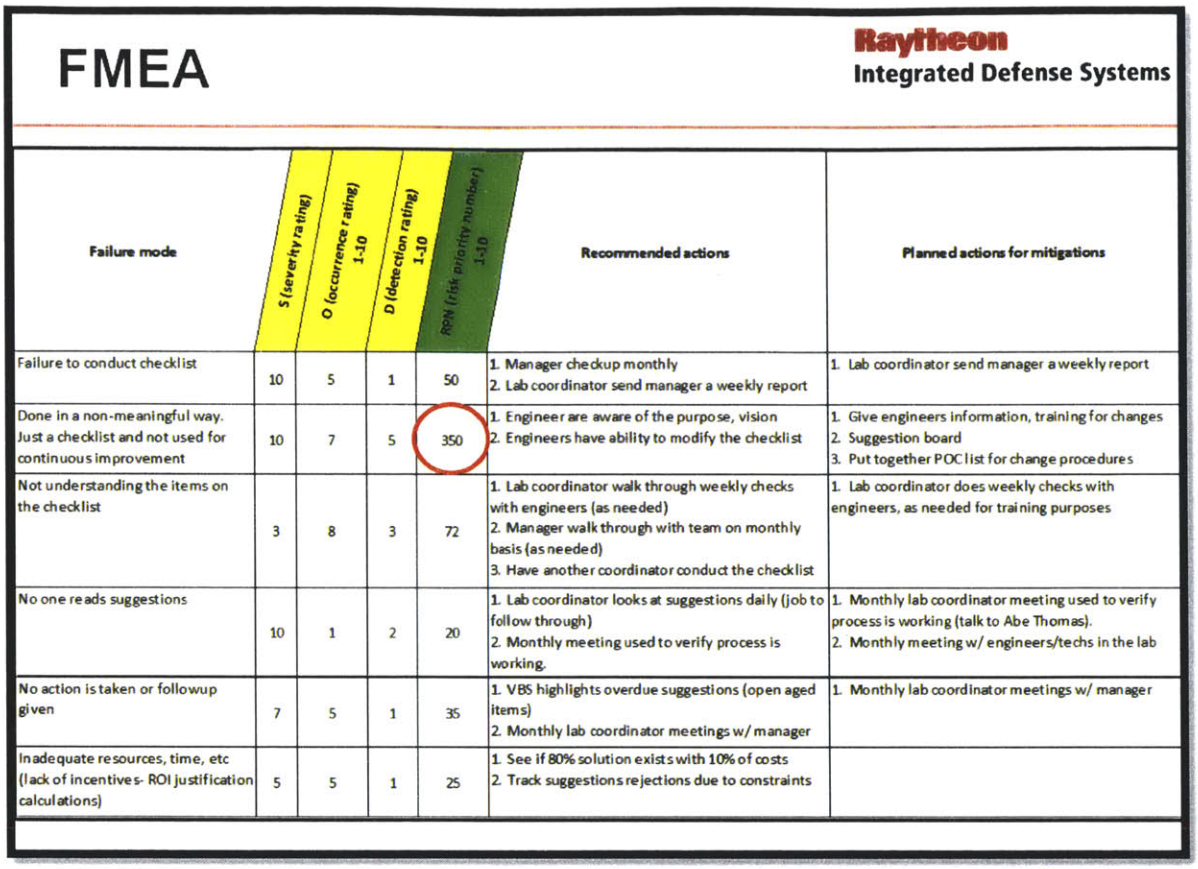


Figure 25: Value Stream Mapping in Raytheon's Electrical Directorate Design

Raytheon discovered that by moving one of the inspections to another area, they could have better information hand-offs and the product to test did not have to move across the facilities. A time study was conducted, which resulted in an 18% reduction in cycle time through the facility under the Aegis Program. This was done by engaging the stakeholders who believed this change would benefit the business and make life easier for them and was easily implementable with zero cost to capital expenditures. It is important to note that the stakeholders involved in this project spanned different groups (program office, logistics, material handlers, inspectors, test labs, etc).

7.2 Examining Failure Modes

Raytheon wanted to ensure that these 2 pilot programs would be a continued success. With full understanding that a failure in these 2 pilot programs would be detrimental to the lean initiative in product development, Raytheon conducted a FMEA (Failure Modes Effect and Analysis). Using this tool, Raytheon was able to identify some of the key failure modes. See Figure 26 to see the FMEA conducted:



FMEA

Raytheon
Integrated Defense Systems

Failure mode	S (severity rating)	O (occurrence rating) 1-10	D (detection rating) 1-10	RPN (risk priority number) 1-10	Recommended actions	Planned actions for mitigations
Failure to conduct checklist	10	5	1	50	1. Manager checkup monthly 2. Lab coordinator send manager a weekly report	1. Lab coordinator send manager a weekly report
Done in a non-meaningful way. Just a checklist and not used for continuous improvement	10	7	5	350	1. Engineer are aware of the purpose, vision 2. Engineers have ability to modify the checklist	1. Give engineers information, training for changes 2. Suggestion board 3. Put together POC list for change procedures
Not understanding the items on the checklist	3	8	3	72	1. Lab coordinator walk through weekly checks with engineers (as needed) 2. Manager walk through with team on monthly basis (as needed) 3. Have another coordinator conduct the checklist	1. Lab coordinator does weekly checks with engineers, as needed for training purposes
No one reads suggestions	10	1	2	20	1. Lab coordinator looks at suggestions daily (job to follow through) 2. Monthly meeting used to verify process is working.	1. Monthly lab coordinator meeting used to verify process is working (talk to Abe Thomas). 2. Monthly meeting w/ engineers/techs in the lab
No action is taken or followup given	7	5	1	35	1. VBS highlights overdue suggestions (open aged items) 2. Monthly lab coordinator meetings w/ manager	1. Monthly lab coordinator meetings w/ manager
Inadequate resources, time, etc (lack of incentives- ROI justification calculations)	5	5	1	25	1. See if 80% solution exists with 10% of costs 2. Track suggestions rejections due to constraints	

Figure 26: Failure Modes Effects and Analysis in Raytheon's Electrical Design Directorate

Raytheon used this tool to identify and rank each failure mode. This was done with both at the user level and with management. The three rating categories are 1) Severity 2) Occurrences 3) Detection. Each category is ranked 1-10.

Severity: If the failure mode occurs, how detrimental will it be on the project? (10 rating is very severe impact)

Occurrences: How often/frequent can we expect this failure mode to occur? (10 rating is very frequent)

Detection: How easy is it to detect this failure mode when it occurs (10 rating is extremely hard to detect).

RPN (Risk Priority Number): When severity, occurrences, and detection are multiplied together, this resulting number is the RPN. Raytheon discovered that the biggest failure mode/risk is having people do the checklist because it *has* to be done rather than it being a tool to really improve workplace organization and safety.

Based on these failure modes, Raytheon brained-stormed some recommended actions and developed realistic plans to help mitigate these risks. This exercise helped Raytheon's stakeholders and leadership realize some of the potential pitfalls so they were more aware of these failure modes. Again, this exercise was targeted in engaging the leaders and stakeholders in keeping the project successful by mitigating some of the potential risks with viable and realistic action plans.

8 Recommendations: Making Raytheon Six-Sigma Training Even Stronger

Raytheon recognized that there are a plethora of opportunities to implement lean in the product development group and not just on the manufacturing shop floor. Thus, the MIT Team recommends that some of these tools be used to engage, inform, and equip Raytheon stakeholders be part of the socialization process, as new-hires enter the Raytheon culture. Each new-hire is required to go through Raytheon's version of Six-Sigma Greenbelt Training known as Raytheon's Specialists Training. See Figure 27 below:

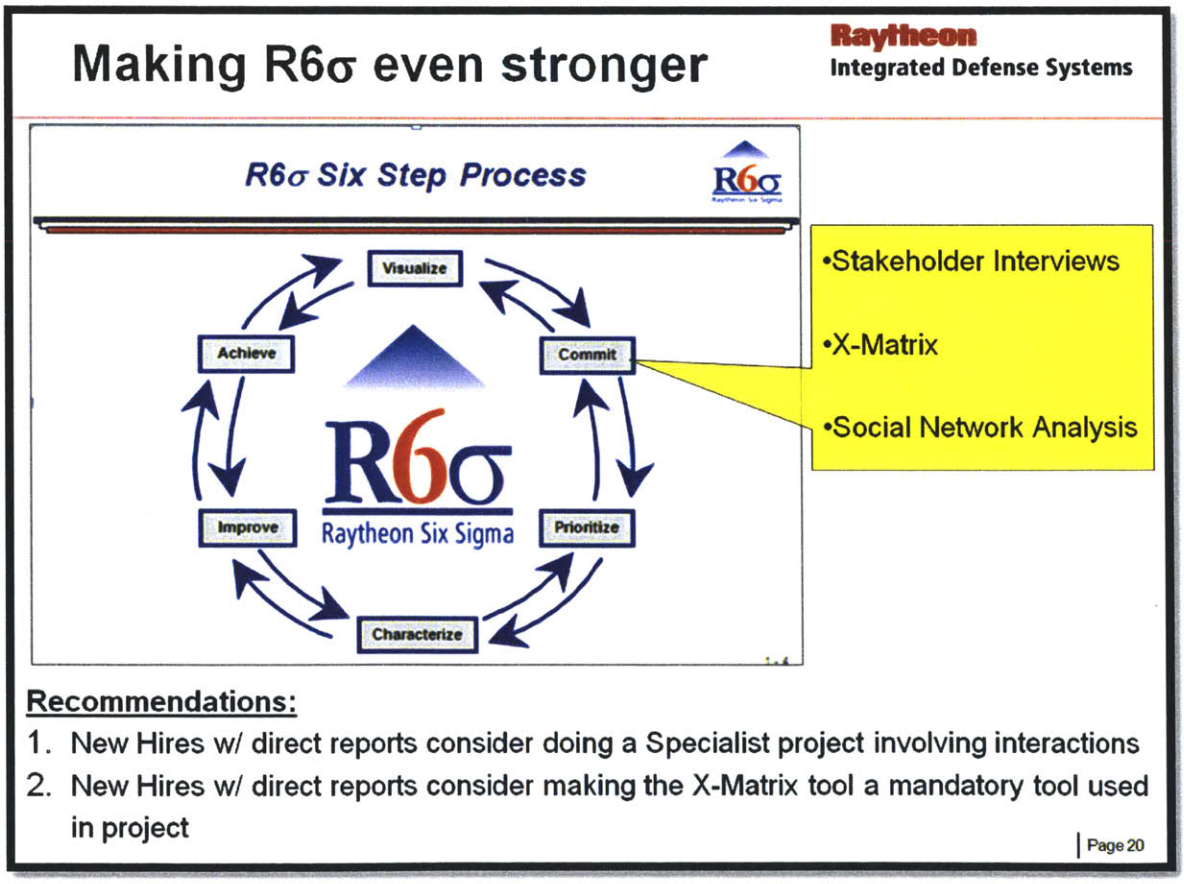


Figure 27: Modified Raytheon Six-Sigma Process

The MIT Team recommends that the "Commit" stage of Raytheon's Six Sigma Cycle become more robust and more integrated within the entire change management approach. The tools to help engage others can be a version of the stakeholder interviews, X-Matrix, and social network analysis. Throughout this entire change management process, it is always useful to understand and utilize the concept that: "Those who plan the battle, rarely battle the plan." [8] Furthermore, there is much opportunity to eliminate waste between hand-offs from group to group. The MIT Team recommends that those new-hires who have direct reports be required to do a Specialist Project involving interactions between different groups and that the X-matrix be used to help understand the organizational architecture with which they will be immersed.

9 Knowledge Transfer

Throughout this change management process, the stakeholders were actively involved, which in the end will be the most valuable asset (experiential knowledge of those who were engaged). However, the MIT Team developed a continuity file that simply explains the task and purpose of each tool along with hyperlinks to files that explains in detail how to utilize these lean tools. See the continuity file below:

2 August 2010

Author: Steven Lee

Email: stevenlee222@gmail.com

This document serves as a continuity file for continuous improvement that others can use to help change be more sustainable. Continuous improvement and transformation is 80% people and 20% tools. Thus, 80% of the focus and time spent during transformation should be with people. *Thus, this continuity file should NOT be used independently, but in conjunction with a point of contact that has gone through this effort.*

The structure of this file is as follows:

1. TASK: Explains **WHAT** needs to be done.
2. PURPOSE: Explains **WHY** it needs to be done.
3. HYPERLINK: Click on Hyperlink to **VIEW** file. (NOTE: For the hyperlinks to work, all files must be saved on the same location, ie- All files saved on the desktop or C or D Drive.

ENGAGE THE WORKFORCE FIRST

1. Push Pull Hybrid Approach
    - TASK: Follow the approach
    - PURPOSE: In order to help change become more sustainable in the long run. Will assist in helping users have ownership in the continuous improvement effort.
    - HYPERLINK: Files\Push-Pull Hybrid Approach.ppt

2. Stakeholder Interviews
   - TASK: Interview the stakeholders. Stakeholders is anyone that would be affected by the change effort (Sourcing, engineers, operations, logistics, leadership, etc)
   - PURPOSE: In order to help change become more sustainable in the long run. Will assist in helping users have ownership in the continuous improvement effort. It's important to understand what is important to the stakeholder and to know what the stakeholder values before one jumps right into a project.
   - HYPERLINK:
     a. Questionnaire for the interviews: Files\Stakeholder.Interview.docx
     b. Results of the interviews (Run in Powerpoint mode- animation): Files\Stakeholder Interviews Summary.ppt

3. X-Matrix
   - TASK: Fill out the X-Matrix using the instructions that are on the hyperlinked file. Ensure when the alignment ratings are conducted, that the questions are asked in the correct format (hover over the interaction cells to view the questions).
   - PURPOSE: In order to identify the gaps in alignment between the quadrants. This will help identify gaps to drive the appropriate behavior. Obviously, if continuous improvement is the behavior we want in the employees, the organizational architecture needs to be set up as such to drive that behavior.
   - HYPERLINK:
     a. Current Condition X-Matrix: Files\Lab_XMatrix.xls
     b. Revised X-Matrix with new metrics, objectives, etc: Files\Recommended.Lab_XMatrix.xls

4. Quality Function Deployment Matrix (QFD)
   - TASK: Fill out the QFD Matrix with weighted ratings. Instructions are imbedded in the hyperlinked file.
   - PURPOSE: This is a way to formally access whether or not to pursue a project given different requirements or criteria. Keep in mind, that one of the criteria should be "stakeholder values", which was collected during the stakeholder interviews.
   - HYPERLINK: Files\QFD weighted matrix.xls

5. Social Network Analysis
   - TASK: Engage others to help formulate a social network map. Draw out the map with the team's input. Define what constitutes a strong network v. a weak one and then rate the network.
   - PURPOSE: When an organization goes through a change initiative, we want to identify a good group that can serve as a pilot. This analysis helps us target the group that has the most potential to spread the continuous improvement effort. Once it's successful in this pilot group(s), it will have the most potential to spread like a virus.
   - HYPERLINK: Files\Social Network Analysis.ppt

6. Create vision
   - TASK: Leadership creates a vision. This should also include how we are going to achieve this vision and with what tools/resources.
   - PURPOSE: This vision should be a direct quotation. The purpose of this is to explain the vision at the start of every meeting, gathering, or kaizan event. This helps align the right tasks and behaviors.
   - HYPERLINK: Files\Vision.ppt

EXECUTE OPPORTUNITIES (2 projects)

Key Take-Aways:

1. *During this process, we MUST continue to engage leadership and the users. For example, it does little good to have a project manager create a tool and then introduce the tool to the user, if the user was not an integral part of coming up with that tool. In this sense, we held sessions where the stakeholders' input was key to developing a solution and a tool that was applicable to their own area.*
2. ***These projects were generated as a result of combining the strategic objectives (X-Matrix) along with the stakeholder values (Stakeholder interviews).*** *In this way, we are working on a project that is both important to management as well as the stakeholders. If we work on a project that doesn't appeal to the stakeholders, then the initiative will die out when management changes out.*

7. Project 1a: 6S Checklist in VBS
   - TASK: Revise 6S Checklist to apply to the engineering test labs.
   - PURPOSE: This checklist is a way to help spur continuous improvement on a basic level. Having work place organization that is clean and organized is the first step to a "Lean" environment. This checklist, however, should be directly applicable to the engineering labs and not simply adopted and used from the manufacturing shop floor. Again, the product of this tool was a culmination of the stakeholders' input and not on an individual effort from the project manager.
   - HYPERLINK: Files\Revised 6S Checklist.docx

   Project 1b: VBS Suggestion Board (Project Book)

   - TASK: Elicit feedback and suggestions from the user level
   - PURPOSE: To drive ownership and engagement from the bottom-up.
   - See Mike Kelly for details @ **Michael_C_Kelly@raytheon.com**

   Key Points of Contact (those actively involved in this effort):

1. Lean Office approval for checklist: John Gould @ **John_Gould@raytheon.com**
2. Revise the checklist in VBS (or anything VBS related including TV monitors): John Day @ **John_P_Day@raytheon.com**
3. Lab coordinator: Mike Kelly @ **Michael_C_Kelly@raytheon.com**
4. EDD Manager: Mike Yeomans @ **Michael_E_Yeomans@raytheon.com**
5. IDS Design for Six Sigma Leader: Kurt Mittelstaedt @ **Kurt_Mittelstaedt@raytheon.com**

VBS Installation instructions onto Laptop Hyperlink: Files\VBS INSTALLTION INSTRUCTIONS.ppt

8. Project 2: Interactions between lab and other functional areas
   - TASK: Identify and Improve the interactions between the labs and other functional areas by using Value Stream Mapping Tools to rate the interactions between pathways and hand-offs
   - PURPOSE: Sometimes, the biggest opportunity for improvement is NOT within one's own area, but during the handoffs between functional areas. For this project, we identified an opportunity to cut out 18% cycle time (7 hours), by relocating the final inspection step to building 1. This was again a top issue identified during the stakeholder interview.
   - HYPERLINK: Files\VSM.ppt

Key Points of Contact (those actively involved in this effort):

1. Lab Engineer: Steve Medeiros @ **S_A_Medeiros@raytheon.com**
2. Lab coordinator: Mike Kelly @ **Michael_C_Kelly@raytheon.com**
3. Aegis Program Lead: **Roger_H_Styskal@raytheon.com**
4. Aegis Program Liaison: **Cathy_M_Moran@raytheon.com**
5. Logistics Manager: Chris Colavita @ **Christopher_J_Colavita@raytheon.com**
6. IDS Design for Six Sigma Leader: Kurt Mittelstaedt @ **Kurt_Mittelstaedt@raytheon.com**

SUSTAIN THE EFFORT:

9. Conduct a Failure Modes Effects Analysis (FMEA)
   - TASK: Identify failure modes and emplace measures to prevent and/or mitigate these failure modes
   - PURPOSE: It's always wise to identify what the potential failure modes or obstacles can be during the implementation phase. This was done with both leadership and the users.
   - HYPERLINK: Files\FMEA.xlsx

10 Conclusions and Next Steps

10.1 Conclusions and Key-Takeaways

Based on the research conducted and actions taken during the internships, Raytheon has discovered some key-takeaways. Raytheon discovered three core elements needed for effective lean transformation:

1. Engage key stakeholders- ensure those who are affected are those who actively participate in helping develop the solutions. These stakeholders are the individuals who need to drive these initiatives/projects. This requires that the project manager act more as a facilitator than the one driving the project.
2. Engage leaders- leaders must remain engaged. This is more than simply offering support or approving the funds necessary to drive the project forward. Leaders must be engaged and must be the engager of their subordinates, as well. This may involve physical presence during these lean transformation initiatives, ensuring these initiatives are key elements that are discussed during routine staff meetings, etc.
3. Modify/refine the organizational architecture to drive the appropriate behavior for change- looking at the details behind the metrics, strategic objectives, stakeholder values, and key processes to analyze alignment is key. Too often employees get too busy to address all the necessary actions to help drive transformation. Thus, certain organizational elements need to be in place to help prioritize during these "busy times".

10.2 Next Steps and Future Opportunities

Raytheon has a challenge ahead of itself. There are some strong mental models that restrict and limit change efforts. Thus, some considerations are outlined below to help drive the transformation of culture:

1. Revise the New-Hire Six-Sigma Training- Those new-hires with direct reports conduct a project dealing with "interaction with different groups" opportunities. Raytheon discovered that there is significant opportunity to address lean efforts *between* different groups. New-hires with no direct reports conduct a six-sigma project within their respective groups.
2. Utilize new tools to help engage workforce- use and integrate into new-hire six-sigma projects people engagement tools such as X-Matrix, stakeholder interviews, social network analysis, etc.
3. Take a step-wise approach to lean transformation- Instead of attempting to change numerous groups at once, use the principles discussed in the social network analysis and engage key groups first and allow them to create further momentum.
4. Educate the Design for Six-Sigma Team and Lean Transformation Teams on the Pull-Push Hybrid Approach. Use the continuity file provided, as well as learning from those individuals who participated using this Push-Pull Hybrid Approach.

11 Contributions and Benefits to Raytheon

The biggest contribution the author has made to Raytheon was to introduce the Push-Pull Hybrid approach, which helped alter the mental models of the traditional Push Approach. Some key results to Raytheon's product development group are noted:

1. Decreased lead time within the product development group by 18 percent for all products in the Receiver/Exciter Lab, which falls under the Electrical Design Directorate.
2. Helped management realize that the metrics and strategic objectives needed modification to help drive the appropriate change behavior.
3. Helped institute a method to capture important suggestions and the implementation of these suggestions in an electronic portal system known as Virtual Business Systems.
4. Helped modify the 5S Audit Checklist to make it more applicable and relevant to the test labs
5. Recommended Push-Pull Approach to Six-Sigma Training to new-hires.

Raytheon's Electrical Design Directorate has adopted this new approach and the rest of the product development group is looking to implement this different approach to the rest of its organization. This approach is still being implemented but still a work in progress. The intended purpose of this research has been fulfilled: To help **create momentum and self-sustaining change in product development through continuous improvement efforts**

12 References

[1] http://en.wikipedia.org/wiki/Defense_contractor snapshot on 16 Feb 2011

[2] Peter W. Singer at http://www.brookings.edu/opinions/2010/0227_defense_regulations_singer.aspx snapshot on 16 Feb 2011.

[3] https://www.fpds.gov/fpdsng_cms/index.php/reports snapshot on 31 Mar 2011

[4] http://www.raytheon.com/ourcompany/ snapshot on 16 Feb 2011

[5] http://www.raytheon.com/ourcompany/history/index.html snapshot on 16 Feb 2011

[6] http://www.raytheon.com/ourcompany/innovation/index.html snapshot on 16 Feb 2011

[7] http://www.raytheon.com/ourcompany/ourculture/index.html snapshot on 16 Feb 2011

[8] http://smartdatacollective.com/Home/21825 snapshot on 28 Feb 2011

[9] Chong, C (1999), "*Where does TQM begin? A case study of two Singapore companies*", in Ho, S.K.M. (ed), TQM and Innovation, Proceedings of the 4th International Conference on ISO 9000 and TQM, Hong Kong Baptist University, Hong Kong, pg 7

[10] Hackman, J.R. & Wageman, R. (1995), "*Total quality management*", Administrative Science Quarterly, June, Vol. 40, pg. 309-42

[11] Dean, J.W. & Bowen, D.E. (1994), "*Management theory and total quality*", Academy of Management Review, Vol.19 No. 3, pp. 392-418

[12] Blackburn, R & Rosen, B (1993), "*Total quality and human resource management: lessons learned from Baldrige Award winning companies*", Academy of Management Executive, Vol.7 No. 3, pg 49-66.

[13] Chong, C (1999), "Where *does TQM begin? A case study of two Singapore companies*", in Ho, S.K.M. (ed), TQM and Innovation, Proceedings of the 4th International Conference on ISO 9000 and TQM, Hong Kong Baptist University, Hong Kong

[14] Chapman, Ross & Murray, Peter, "*From continuous improvement to organizational learning: development theory*", The Learning Organization; 2003, pg 272-273.

[15] Chapman, Ross & Murray, Peter, "*From continuous improvement to organizational learning: development theory*", The Learning Organization; 2003, pg 275-276.

[16] Hedberg, B. (1981), "*How organizations learn and unlearn*", in Nystrom, P.C. and Starbuck, W.H. (Eds), handbook of Organisational Design, Oxford University Press, London, pg 8-27.

[17] Daft, R.L. & Weick, K.E. (1984), "*Toward a model of organizations as interpretations systems*", Academy of Management Review, Vol. 9, pg 284-95.

[18] Hackman, J.R. & Wageman, R. (1995), "*Total quality management*", Administrative Science Quarterly, June, Vol. 40, pg. 309-42

[19] Miller, D. & Friesen, P.H. (1980), "*Momentum and revolution in organization adaptation*", Academy of Management Journal, Vol. 23 No. 4, pg 591-614.

[20] Nightingale, Deborah & Stanke, Alexis & Bryan, Terry (2008), "*Enterprise Strategic Analysis and Transformation (ESAT), Release 2.0*, pg 47-48.

[21] Nightingale, Deborah & Stanke, Alexis & Bryan, Terry (2008), "*Enterprise Strategic Analysis and Transformation (ESAT), Release 2.0*, pg 39.

[22] Youker, Robert (1977), "*Project Management Quarterly*", Vol VIII, No. 1, March 1977, pg 3.

[23] Kouzes, James & Posner, Barry, *The Leadership Challenge*, John Wiley & Sons, Third Edition, 2002, pg 49

[24] Kouzes, James & Posner, Barry, *The Leadership Challenge*, John Wiley & Sons, Third Edition, 2002, pg 50

[25] Mittelstaedt, Kurt, Leader Design for Six-Sigma Integrated Defense Systems, Interview, March, 2010.

[26] Kim, W. Chan & Mauborgne, Renee (2003), "*Tipping Point Leadership*", Harvard Business Review, April 2003, pg 41.

[27] McManus, Hugh, PhD (2005), "*Product Development Value Stream Mapping (PDVSM) Manual 1.0*", Pg. 57

[28] McManus, Hugh, PhD (2005), "*Product Development Value Stream Mapping (PDVSM) Manual 1.0*", Pg. 58

[29] Nightingale, Deborah, http://lean.mit.edu/areas-of-research/research-at-lai-overview.html, accessed on 4 April 2011.

[30] Arabie, Phipps & Boorman, Scott & Breiger, Ronald, "*An Algorithm for Blocking Relational Data, with Applications of Social Network, Analysis and Comparison with Multidimensional Scaling*", Technical Reporting No. 244, December 1974.

[31] Nightingale, Deborah. Integrating the Lean Enterprise. Lecture at the MIT School of Engineering, Systems Engineering. September 2009.

[32] Haggerty, Al and McManus, Hugh & Murman Earll (2005), "*Lean Engineering: Doing the Right Thing*", Whitepaper, August 2005.

[33] Honeywell, International. Aerospace Division in Phoenix, AZ, 2006-2009

[34] Honeywell, International. Aerospace Division in Phoenix, AZ, 2006-2009

[35] http://www.honeywell.com/sites/servlet/com.merx.npoint.servlets.DocumentServlet?docid=DE19AC833-E55B-99BC-67DD-873ECD4E448C snapshot on 4 Mar 2011.