Utilization of Visual Metrics to Drive Intended Performance

By

Daniel Wolbert

B.S., Chemical Engineering, University of Michigan – Ann Arbor (2000)

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

Master of Business Administration
AND
Master of Science in Mechanical Engineering

In conjunction with the Leaders for Manufacturing Program at the
Massachusetts Institute of Technology
June 2007

Signature of Author__

MIT Sloan School of Management
Department of Mechanical Engineering
May 11, 2007

Certified by________________

David E. Hardt, Thesis Supervisor
Ralph E. and Eloise F. Cross Professor of Mechanical Engineering

Certified by________________

Roy E. Welsch, Thesis Supervisor
Professor of Statistics and Management Science

Accepted By________________

Lallit Anand, Chairman, Graduate Committee
Department of Mechanical Engineering

Accepted By________________

Debbie Berechman
Executive Director of Masters Program, MIT Sloan School of Management

This page intentionally left blank

Utilization of Visual Metrics to Drive Intended Performance

By

Daniel Wolbert

Submitted to the Sloan School of Management
and the Department of Mechanical Engineering
on May 11, 2007
in partial fulfillment of the requirements for the degrees of

Master of Business Administration
And
Master of Science in Mechanical Engineering

ABSTRACT

In recent years the American industrial landscape has undergone tremendous change as companies have worked to adopt Lean practices. This transformation has been difficult, but necessary, as American companies work to remain competitive with foreign competitors. A key enabler of these Lean transformations has been the use of visual metrics to communicate how a process has performed as well as to set goals for future performance. The challenge is to first identify what data is available and then create metrics that encourage and reward Lean behaviors.

This thesis explores the introduction of visual metrics for a part inspection process at the Raytheon Company. Prior to the introduction of these metrics, there was limited ability to determine how the process was performing. As a result, downstream customers were able to track when a part entered the inspection process but were unable to predict when the inspection would be completed. This introduced a risk to the process and created a sense of frustration through the facility.

The visual metrics for the inspection area were created on a series of visual dashboards that display common Lean metrics, such as cycle time and backlog (or work-in-process). Through these dashboards the area will be able to understand how it is performing and initiate continuous improvement projects to improve performance.

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

Thesis Supervisor: David Hardt
Title: Ralph E. and Eloise F. Cross Professor of Mechanical Engineering

Acknowledgements

First and foremost, I would like to thank the LFM program and each of the administrators and professors associated with it. I could never have imagined the level of support and commitment has towards both current and past students. It truly is a unique, two-year transformational experience that I will forever remember.

Second, I would like to thank the Raytheon Company and the employees of the Integrated Air Defense Center in Andover. Specifically, I would like to thank John Day for his ongoing mentorship, Roger Hinman for his knowledge and thoughtful comments throughout the internship and everyone else involved in my project including, but not limited to, Mark Recco, Joe Shepard, Mary Anne Gemma and the entire incoming inspection area.

Thank you to my advisors, Ray Welsch and David Hardt, who helped guide me throughout the internship and in the preparation of this thesis.

Thank you to my classmates in the LFM class of 2007. The laughter and memories we have shared will last a lifetime.

Finally, and most importantly, I would like to thank my family. My father and mother for their unending support throughout my entire academic journey, and each of my siblings, Dave, Michelle, Marie, and Derrick for the love and respect you have given me through the years.

Table of Contents

List of Figures

This page intentionally left blank

1 Introduction

1.1 Overview

This thesis explores the use of visual metrics to drive Lean behavior in an operations environment. Lean implementations have become increasingly common in recent years as American companies have worked to remain competitive with foreign competitors. A key tenet in these implementations has been the ability to understand processes through the visualization of metrics. Visual indicators are designed to convey current information that is relevant to the process and can result in an action being taken to modify or improve the process. This information serves to make the process transparent where managers and line workers alike are able to understand process performance. As a result, visual indicators are able to create a common baseline from which to improve the process.

The research for this thesis occurs at the Integrated Air Defense Center in Andover, MA for the Raytheon Company. Similar to much of the aerospace and defense industry, the Raytheon Company has been undergoing a Lean transformation. This has been a challenge given the historical structure and incentives within the industry. As Raytheon has evolved it has placed a major emphasis on the implementation of Lean tools, including visual indicators, to support this transition.

The overall goal of this research project is to use visual metrics to provide the manufacturing floor and program office visibility to the supply chain. The term visibility is often used when a process is not well understood and must be defined more completely. In this situation, the majority of parts entering the IADC facility are inspected upon receipt. When a part enters the inspection process it often remains there for an unknown period of time while downstream customers wait for it. With these given conditions of the incoming inspection process, a "visible" process has been defined to be one that provides the ability to:

1. Identify bottlenecks in the inspection process
2. Identify sources of variation in cycle time
3. Provide the ability to easily locate a part in the inspection process

These three goals will provide fundamental performance metrics, creating a foundation for future continuous improvement projects.

1.2 Organization of Thesis

The thesis is organized into 6 chapters as described below:

Chapter 1 – Introduction: Contains information on thesis

Chapter 2 – Defense Industry Transition to Lean: Describes at a high level the historical background of the defense industry, from the Cold War era to the current state. It additionally discusses the role of Lean and incentives within the industry.

Chapter 3 – Company and Facility Overview: Details information about Raytheon company, where the research for this thesis was performed.

Chapter 4 – Driving Performance Through Lean Metrics and Visual Indicators: Discusses the role of metrics and how one should go about identifying the proper metrics. Additionally, illustrates the use of visual indicators and how they drive performance.

Chapter 5 – Case Study of Implementing Performance Metrics: Initially provides background information on the need for performance metrics within the incoming inspection area. Each of the visual dashboards and performance metrics created are described in detail.

Chapter 6 – Conclusion and Recommendations: Summarizes the thesis and makes recommendations.

2 Defense Industry Transition to Lean

To fully understand much of the motivation behind Raytheon's Lean transformation, it is important to understand how the defense industry has changed over time. This chapter explores this progression.

In 1993, the Air Force raised the question "Can the concepts, principles and practices of the Toyota Production System be applied to the military aircraft industry?" as a means of improving production efficiencies. This led to the creation of the Lean Aircraft Initiative at MIT designed to answer that question and enable the development of best Lean practices within the industry[1]. Since then, the defense industry has been enduring a major change in production philosophy as it has shifted from its historical manufacturing practices to adopting Lean principles. Prior to this shift the industry exhibited the typical symptoms of mass production: high inventories and work-in-process, long wait times, and high flow time variability, all leading to increased cost to the tax payer.

2.1 Historical Operation of Defense Industry

From the end of World War II until the beginning of the 1990s, the United States and Soviet Union were engaged in the Cold War. While there was limited direct confrontation, both sides worked aggressively to build bigger, stronger, more

[1] Lean Aerospace Initiative, "Lean Aerospace Initiative Overview Presentation", October 2005

technologically advanced militaries in an attempt to gain an advantage over its adversary. With this goal, the emphasis was consistently on the performance of military systems, regardless of the time required or cost to build. American defense firms received large amounts of funding for development and production of these systems. This investment developed an immeasurable number of cutting edge technological improvements such as nuclear submarines, the B-2 bomber, advanced jet fighters, and space travel. These improvements not only directly benefited the military, but they often trickled down to commercial products in the form of civilian jet transport and worldwide communications to name a few[2].

Contracts between the government and defense contractors were typically "Cost-Plus" during this time. A cost-plus contract is structured so the full development and production cost is reimbursed to the company along with an additional fee for the company. This type of contract is used when a large amount of research is required or there is a great deal of uncertainty or risk associated with a new project[3]. This structure provided the proper incentives for the contractor to develop the technological performance sought by the government. However, by fully reimbursing all development costs, there was little motivation for the government contractors to operate more efficiently and reduce costs. The cost of building excess capacity or holding too much inventory was funded by the government rather than the company[4] Contrasted against

[2] Murman, Earll et al, "Challenges in the Better, Faster, Cheaper Era of Aeronautical Design, Engineering and Manufacturing," MIT - Lean Aerospace Initiative, 2000
[3] General Services Administration and Department of Defense, Federal Acquisition Regulation, Volume 1, Subsection 16.3, p 367, 2005
[4] Gansler, J.S. United States Under Secretary of Defense, Memorandum Regarding Incentive Strategies for Defense Acquisitions, 2001

the public sector where companies must improve efficiencies to survive in a competitive industry, government defense contractors were often accused of wasting tax payer dollars.

2.2 Defense Industry in Post-Cold War Era

The end of the Cold War marked a major transition point for the US Military. Beginning in the early 1990s, the US Congress began cutting back the number of military personnel and bases. In the absence of a major military adversary, the defense budget was cut and the defense industry saw much of its funding dry up. Then, in 1993, Secretary of Defense William Perry requested that the top defense companies consolidate and merge to reduce the overall overhead cost in the industry. To further encourage such a strategy he pledged government support and fast approval of such mergers[5]. While many firms consolidated, others folded and several of the major firms needed to resort to layoffs and mergers to remain alive[6]. The structure of the industry that had existed for so many years was rapidly changing.

The cut in the defense budget forced the Department of Defense to closely examine its procurement process. It no longer was able buy the most advanced weapons at whatever cost; it needed to spend the budget effectively. This shift in policy was reflected in the Report of the Defense Science Board Task Force on Defense Acquisition Reform prepared for the Department of Defense. The report emphasized the "adoption of

---

[5] Flamm, Kenneth, *Post Cold-War Policy and the US Defense Industrial Base*, The Bridge, Vol. 35, No. 1 pp5-12

[6] Gholz and Sapolsky, *Restructuing the US Defense Industry*, International Security, Vol. 24, No. 3 pp5-51

commercial practices to the maximum extent possible." In this way the DoD aimed to establish an environment where the defense contractors were no longer supported to the level they were previously and functioned as if they were in a competitive industry, incurring direction from the marketplace, cost pressures and the need to be more efficient amount other things.

2.3 Lean Manufacturing in the Defense Industry

This attempt to transform the industry from performance focused to cost conscious fit well with the Lean philosophy. The defense industry was ripe with much of the waste that Lean works to reduce – excess inventory, excess capacity, long wait times between production steps, and general process inefficiencies. Recognizing this, many of the leading aerospace and defense companies formed the Lean Aerospace Initiative to help them implement Lean manufacturing principles. The large American automakers have been forced to adopt Lean in response to the intense competition they face from their Japanese competition. In contrast, the defense industry did not face that same threat that would have encouraged more efficient production capabilities earlier.

Apart from the many cultural issues all companies face in the transition to Lean, the defense industry was faced with many incentive issues. There is a tension between the structure of the cost-plus contract and Lean. When all costs for a project can be passed on from the company onto the government, there is no financial incentive to improve process efficiency. In addition, many of the defense firms are allowed to recognize revenue as a project is worked on and costs are incurred due to the significant duration of a defense program. This further provides incentives to purchase inventory before it is needed or produce finished goods before the customer asks for them, two actions that are contrary to Lean production.

The Department of Defense Incentives Guidebook published in 2001 emphasized that contracts should be structured in a way that rewards the desired behaviors.

> *Defense acquisition processes must be more efficient and cycle time must decrease to meet the wide-ranging set of requirements imposed by today's unstable national security environment. Thus, the DoD suppliers must improve their efficiency and cycle time. They must consider and adopt practices proven effective in the highly competitive commercial marketplace. Lean industry principles and best practices should be recognized and rewarded*[7].

The recognition and rewards can come in the form of financial rewards for current projects, but also whether or not a contractor has adopted Lean can be a factor in awarding future contracts. With this guidance the DoD explicitly dictated to its contractors that they must implement Lean practices. It is clear that Lean manufacturing has become a vital part of the defense industry.

---

[7] United States Department of Defense, *The Incentives Guidebook*, 2001

3 Company and Facility Overview

Building on the industry background, this chapter provides information about the overall company, the division, and the facility that this research was performed in. Additionally, the Raytheon Six Sigma program is described as it is the company-wide initiative that drives much of the Lean transformation within the company.

3.1 Raytheon Company

Since its founding in 1922, Raytheon has used technological innovation to become an industry leader in commercial and defense sectors. Included in the list of inventions Raytheon pioneered are commercial microwave ovens, miniature tubes for hearing aids, and the first successful missile guidance system[8].

Today, Raytheon is headquartered in Waltham, Massachusetts and recorded sales of $21.9 billion in 2005. It is organized into seven major business units: Integrated Defense Systems, Aircraft, Intelligence and Information Systems, Raytheon Technical Services, Missile Systems, Space and Airborne Systems, and Network Centric Systems. Each of these business units fits into Raytheon's overall strategy of providing integrated solutions to its defense and commercial customers.

[8] "Raytheon Company: About Us: History" http://www.raytheon.com/about/history/index.html, 5/2/2007

3.2 Integrated Defense Systems Division

The work for this thesis was performed within the Integrated Defense Systems (IDS) business unit, headquartered in Tewksbury, MA. IDS delivers integrated land and sea based systems designed to identify and respond to incoming threats. It is the preeminent provider of ballistic missile defense radars, capable of identifying incoming threats from thousands of miles away. IDS's customers include the United States armed forces, Missile Defense Agency, and several foreign governments. 2005 sales totaled approximately $3.5 billion[9].

3.3 Integrated Air Defense Center

The Integrated Air Defense Center (IADC) is the main manufacturing site for IDS, producing a range of products from circuit cards and wave oscillators to completed radars. Opened in 1970s, this facility was characterized by mass production and strong unions for many years. Beginning in 2000, it has undergone significant changes as it has attempted to adopt a Lean operating environment. Management has worked to create a collaborative environment with workers at all levels. There is an increasingly deep understanding and commitment to Lean principles throughout the entire organization. While this change has not been an easy transition, the facility's success has been recognized by receiving two consecutive Shingo Awards for excellence in manufacturing.

[9] "Raytheon Company: Businesses: About IDS" http://www.raytheon.com/businesses/rids/about/index.html, 5/2/2007

The IADC functional groups are organized across two primary dimensions: value streams and program offices. In this context, the term value stream is synonymous with manufacturing area. These value stream areas include circuit card assembly, cable assembly, microwave, and final assembly. The program offices are aligned with Raytheon IDS' primary missile defense programs that are under production, such as the Ballistic Missile Defense Systems (BMDS) and Cobra Judy Replacement (CJR) programs.

3.4 Raytheon Six Sigma

At a corporate level, the Raytheon Six Sigma program promotes a single method of operating across the entire enterprise. According to the Raytheon website, "Raytheon Six Sigma training programs continue to unite organizations to common goals: maximizing customer value, transforming our culture and cultivating knowledge-based processes."[10] The program served as a valuable foundation that helped to integrate new business acquisitions throughout the 1990s into a single corporation. Although it is difficult to place a monetary value on the program, it is viewed as important investment in the long term success of Raytheon. While not modeled directly after the Six Sigma program popularized by Motorola and General Electric, it combines many elements of Lean to effectively form a Raytheon Operating system. Instead of focusing heavily on

[10] Raytheon Website - Raytheon Six Sigma Page http://www.raytheon.com/about/r6s/index.html, 5/2/2007

quantitative analysis that only a portion of the employee population can grasp, it emphasizes identifying process improvements and cost savings by all employees.

Every exempt employee and all summer interns at the IADC are required to attend Six Sigma training shortly after joining the company and must complete a project to become Six Sigma Specialist certified. The worker must identify a "Burning Platform" for change and implement improvements to rectify this issue. This initiative creates a common foundation and consistent theme throughout the facility of following a scientific methodology to create process improvement. Managers have annual goals of having 100% of their employees Six Sigma Specialist certified by the end of year. As a result, every worker has an understanding behind the rationale of the many process improvement projects going on at any given time.

The Six Sigma program enabled this research project to be successful. As workers at all level work to identify projects to increase productivity, they become more receptive to projects initiated outside of their own areas. This was particularly important because the researcher did not in the Incoming Inspection group. It was easy to articulate the goal of this research project to the Incoming Inspection group and quickly build their support, forming a Six Sigma project team in the process.

4 Driving Performance Through Metrics and Visual Indicators

An ongoing challenge for managers of manufacturing companies is how to get workers to perform most effectively. Typically, managers choose to positively motivate the employee by promising greater rewards for higher productivity, or conversely threaten negative actions if there is not a productivity increase. Whichever method is chosen, the decision on how to measure productivity can result in a wide range of behaviors from the employee. The difficulty is in identifying how to measure the desired performance, as the measurement used can greatly influence results. This chapter discusses these challenges and describes some of the methods to overcome them.

4.1 Identifying Proper Metrics

The first step in designing the proper metrics is to identify what the end goal is for a process or individual. For example, when the IADC facility is building a radar the overarching goal is to produce a reliable and highly sophisticated radar that is on time. For a production operator assembling sub-components the metrics chosen must be in line with this higher level goal. In this case, tracking metrics such as quantity produced, cycle-time, and rework percentage for an operator would illustrate how that individual is helping the facility to achieve its goals.

Neville McCaghren, a member of the LFM class of 2005, further identified three important considerations when designing metrics:

1. Audience – Different metrics will be required for individuals at various levels within an organization. At the production operator level, metrics around cycle time and part quality may be most relevant. Further up in the organization a Group Vice President will be more concerned with overall revenue and profitability.
2. Decision Making Time Horizon – A high speed production process uses SPC requires near real time data to identify quality issues and minimize the amount out of spec parts produced. In contrast, investors anticipate making buy or sell decisions based on quarterly or annual announcements.
3. Desired outcome – If an employee is rewarded based on a performance metric, the employee will act in a manner that will maximize that performance metric.[11]

With these factors in mind, a manager can create several different types of performance metrics designed to increase the overall performance and productivity of a team or organization.

4.2 Role of Visual Indicators

There is a constant flow of information between teams, individuals, managers and direct reports. As different events or issues arise in a factory, the timeliness and accuracy of

[11] McCaghren, Neville, *Enabling Process Improvements Through Visual Performance Indicators*, MIT LFM Thesis, 2005

information can vary based on how important it is to convey the information. For example, one would not be concerned if the cafeteria has run out of mashed potatoes but if a high volume production process suddenly started producing every part outside of specifications then people who are able to fix that must be notified immediately. In this context, the method of communication can be as important as what is actually conveyed. The most effective methods of communication can be written, such as in a memo or an e-mail, verbal, in a conversation between two people, or visual, a display that people can see and can vary based on the situation.

Visual communication can be the most effective to convey information to a large audience. Commonly a display detailing key metrics that reflect performance is setup in a production area. If it is well designed, everyone within the area will know how well they are actually performing. In addition, anyone entering the area such as project managers or plant management will be able to immediately know how the area is performing, without needing to read a report. The visual communication makes the area transparent to everyone.

Beyond the ability to communicate to more people, visual communication can remove subjectivity surrounding how the information is conveyed to different groups. Consider an example where a production team has fallen behind in its weekly goal. If the team manager receives a report illustrating this gap in production and decides to speak with his team there is a possibility that his team may interpret what he says differently than intended. The managers message may be that they need to work together and they can make up the gap, but the workers who did not know how their team was relative to their goal could mistake what he is saying as an accusation that they didn't work hard enough in the beginning of the week. This situation can be contrasted against a clearly defined visual display that lists the weekly goals and weekly production to date, everyone from the manager to the team member is able to understand where the team is relative to the goal. There is no surprise or misinterpretation when the manager talks to the team since everyone knows they are behind[12].

4.3 Use of Real-Time Metrics at the IADC

Historically within the IADC production lines, as in many other manufacturing facilities, data was collected automatically but not presented until a report was printed the next day or later. While this was useful to discuss what happened the previous day and create plans to improve quality or efficiency, no action was able to be taken when it could have made an immediate impact. Beginning in 2003, the IADC initiated a program called the Visual Factory to implement real-time statistics for operations. During this time most of the production information at the IADC was moved into a data warehouse, enabling near real-time access to the data.

4.4 Use of Andon Boards

[12] Greif, Michael, *The Visual Factory*, p. 4-7, Productivity Press, 1991

An andon board is a visual control device in a production area that gives the production status and alerts team members to production problems[13]. Andon boards are common Lean tools and an example of a powerful, real-time visual indicator.

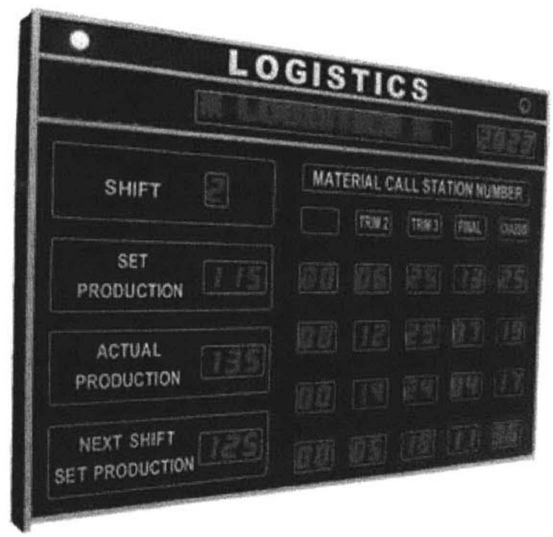


Figure 4-1 – Electronic Andon Board

Related to the Andon board (See Figure 4-1) is the Andon cord, which is pulled when a production problem occurs. An alert then appears on the Andon board and, depending on the company or facility, the production line is stopped until the problem is resolved. When implemented effectively, the Andon board and cord combination allows a production line to fix problems as they arise, preventing future incidents.

Historically, the use of the Andon tools has resided on the production floor. However, there are processes not directly on the production floor that can shut down the line or otherwise delay production if there is a problem. As an organization moves to a Lean

---

[13] Womack, James and Jones, Daniel, *Lean Thinking: Revised & Updated*, p. 347, Freepress, 2003

Enterprise the use of the Andon concept becomes applicable outside of the production line. For instance, if there is low inventory of a raw material which must be reordered immediately then an Andon signal would be relevant to focus the efforts of the procurement team to obtain that replacement order as quickly as possible. This researcher has been unable to identify the use of an Andon board outside of the production line, but explores the concept in a later section.

5 Case Study of Implementing Performance Metrics

This chapter describes the processes impacted by the research project, the environment that the project occurs in, and the visual indicators created to drive Lean behavior.

In order to identify the scope of the research project, I met with several members of the Missile Defense program office and leaders of the manufacturing value streams. A consistent sentiment was the "lack of visibility" in the supply chain for the microwave area. Lack of visibility is a term that is often used to describe a process that is unknown and not well understood. As such, a critical first step to ground project objectives was to fully define the lack of visibility in this particular situation.

5.1 Part Ordering Process

The Microwave area builds sub assemblies that are used in the construction of a phased array missile defense radar. This area depends on many different suppliers to provide high precision components. In the event that there is a part shortage or delivery delay, the area may need to stop production to wait for replacement parts. Since most of the assembly area is building parts for a single product, management is unable to shift production to another product line. This delay is further exacerbated by the way contracts are often structured: Raytheon is able to bill its customers as work is performed.

In other words, every hour that is worked directly translates to revenues. When there is a line stoppage the company is unable to earn that revenue.

Once the need for a replacement part is realized, there is a coordinated and strenuous effort initiated to get that part to the assembly line. The Microwave area management works with the program office team lead and supply chain specialist to contact the vendor and obtain replacement parts. The vendor then sends the shipment priority to the IADC where it is received. Once the part is received it undergoes an inspection process before moving to the assembly line. It is in this inspection process where there is a lack of visibility.

The time required to inspect and provide a quality approval for a part is highly variable and not well understood throughout the facility. Within the MRP system there is a 5 day cycle time for the inspection process, but certain parts can exit the area in less than a day while other parts remain in the area for over 30. If the part is not needed immediately then the cycle time through the area is not important, but if it is a replacement part then the time delay in the area is a major issue.

5.2 Material Verification and Test

A full 70% of all parts are inspected in the Material Verification and Test (MV&T) area. While it understood that inspection upon receipt is a non-value added activity and contrary to many Lean philosophies, the risk of having a bad part reach the production line and the resulting line stoppage is so costly that incoming inspection is considered a worthwhile expense. There are efforts to work with suppliers to increase the reliability of source inspections and reduce the need for the MV&T area.

5.3 Process Stakeholders and Agency Issues

With the layout of the functional organizations, there is a different level of commitment and risk associated with each of the key stakeholders involved in the inspection process. Agency issues arise at two levels because the department performing the work is different than those who must deal with the consequences if the work is not performed correctly.

The first level of agency issue arises between the design engineers and the performance excellence area. When a part is first introduced into production, the design engineer specifies the quality testing procedures. The incentives for the design engineer are to ensure only good parts are used in the end product. As a result, if a test is marginally useful yet takes a very long time to do, the design engineer may still elect to have the test done since process efficiency is not directly his responsibility. There may be non-essential tests that increase the amount of time a part spends in the MV&T area.

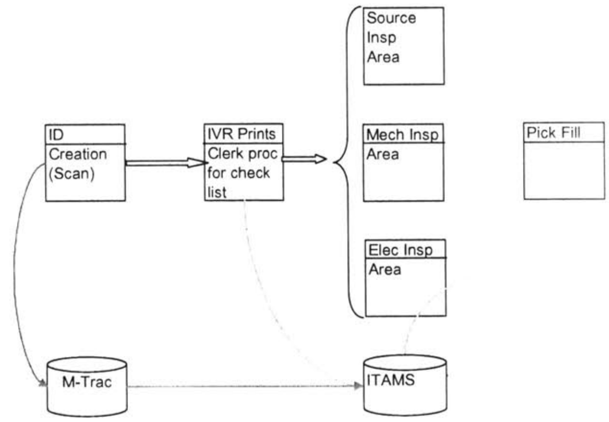
The second level of agency issues arises between the MV&T area and the production lines. The role of incoming inspection could be considered primarily to identify part non-conformances. The production leads need to have high quality parts for their line available. Speed is more critical for the production leads than the quality control individuals. If a part remains in inspection too long, it is the production area that is harmed since they are missing the part, while there is no true negative impact to the MV&T.

5.4 Part Process Flow Through MV&T

There are two main testing areas, Mechanical and Electrical inspection. Mechanical inspection performs many of the physical tests, including dimensional analysis and counting the number of parts received. In the Electrical inspection area the electric characteristics of a part are tested. The Mechanical and Electrical inspection areas are located in separate areas within the IADC, so when a part needs to be transferred between the two it may take a while.

Each of the parts may follow a different path once it inters the inspection area based upon the testing procedures mandated by the design engineers. All parts received into the facility are input to a tracking system known as M-Trac. This tracks the package until it exits the receiving area into the Main Stores area or even the production line if it is an urgently needed part. Additionally, the part travels with an Inspection Verification Report (IVR) that contains what testing areas it must travel to. Refer to Figure 5-1 for a Value Stream Map of the area.

Receiving Current



				Total:
P/T	5 min	5 min	6 mins	**16 min**
W/T	6 hrs	8 hrs	5.6 hrs	**19.6 hrs**
FPG	95%	99.20%	99.50%	**97.50%**

Figure 5-1 - Incoming Inspection Value Stream Map[14]

If the part is received from a supplier who has historically displayed high quality, the part is considered to be a "Verified Quality Part" and sent directly to inventory stores. Approximately 28% of all parts received are VQP.

The non-VQP parts are then placed on racks where they remain until one of the MV&T team leaders is able to pick it up, read the IVR to determine which testing area the part needs to go to, and take it there. The part is then tested at the station. Once the testing is completed, the IVR is then read again to see if additional testing is needed. If there is another test needed, it is then taken to another station for the test.

A part might require a combination of Mechanical and Electrical testing so it can go back and forth between the areas between the testing areas. Within these areas, there are over 200 individual stations a part can be at during the inspection process. These stations

[14] Value Stream Map created by Raytheon IDS Six Sigma project team

include people's desks, waiting racks, and inspection stations. Each time a part moves between stations or testing areas it is placed on transportation or buffer racks when it awaits testing. While there is a priority system in place, it is loosely followed based on the production schedule. When the part moves between areas its priority might get lost for a period of time among all the other parts waiting to be inspected.

Once all of the testing is completed, the part is then ready to be moved into inventory stores or taken to the production line for use. With all the transportation between areas and the waiting time on racks, if a part requires multiple tests it can spend days to weeks in the MV&T area.

ID_NUM	LOC	LOC DESC	TIMESTAMP
652IBE	01	AT RECEIVING	12/16/2006 6:09:04 AM
652IBE	02MA	ELECT OFFICE REVIEW - T.JC	12/16/2006 6:09:04 AM
652IBE	02	RECEIVED INTO OFFICE	12/16/2006 6:09:04 AM
652IBE	17PR	VERIFIED QUALITY PART REV	12/16/2006 6:09:04 AM
652IBE	80	ELECTRICAL ASSIGNMENT	12/18/2006 9:04:06 AM
652IBE	79	NO HIT	12/19/2006 1:57:22 PM
652IBE	7301	PICK REQUESTED	12/19/2006 1:57:22 PM
652IBE	7302	PICK FILLED	12/21/2006 10:51:25 AM
652IBE	08VM	VISUAL MEASUREMENT	1/3/2007 11:29:16 AM
652IBE	08ET	XRF END TERMINATION	1/3/2007 12:51:44 PM
652IBE	71	SOLDERABILITY	1/30/2007 9:56:45 AM
652IBE	27	ENG PROB RACK ELECT	1/30/2007 10:15:41 AM
652IBE	85EE	MATERIAL IN IES ELECTRICAL	2/1/2007 2:41:22 PM

Figure 5-2 - Sample Package Transaction Record

Figure 5-2 is the transaction record for a package and details a representative example of the path a part received can follow. After being received originally on December 16 it was visually inspected in the Mechanical inspection area as well as being tested for electrical properties. It failed the electrical inspection and was awaiting additional testing and next steps as of February 1. The overall process was characterized by several quick tests upon receipt then long wait times between tests as it sat on a rack to be tested. Without an individual following this package it can remain in the area for months before exit.

5.5 Impact of Lack of Information

Throughout most of the ordering process a part is able to be tracked easily. There are order dates on purchase orders, vendors communicate when the part will be sent out, and shippers provide tracking and expected delivery information. However, once the part enters the incoming inspection process, there is limited information. A downstream customer can locate which station the part is at, but has no idea what station it goes to next or when it will complete the overall inspection process. The area is known as a "Black Hole" because it is unclear what happens to a part when it gets there. See Figure 5-3 for a graphical depiction of the part flow to the production line.

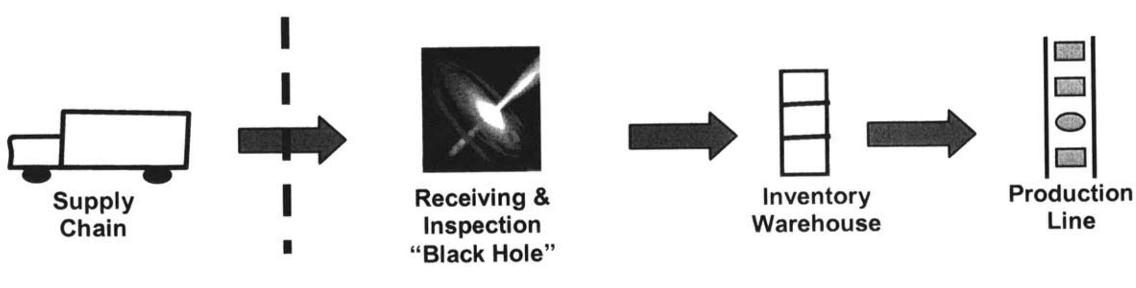


Figure 5-3 - Typical Part Flow to Production Line

There are limited metrics available that detail the performance of the area. This researcher viewed an automated report that tracked weekly average cycle time graph that listed the average cycle time at approximately 4 days. However, when management of the area was asked, they could not list the beginning or ending points of the process where that the cycle time measured. To measure backlog, management does a visual approximation of the backlog. When there appear to be too many boxes on the floor in the inspection area, overtime is authorized to reduce the backlog. There is no grounded measurement of the number of packages that are in the area at any given point in time.

Lack of available information is a common management challenge. The downstream customers, specifically the production line, closely watch the inspection process while waiting for their part. There are several consequences that arise from the lack of information and communication:

1. Inability to set part availability expectations

   The only approximation of when a part becomes available is the 5 days that are listed in the MRP system. The MV&T area follows the testing specification on the IVR but has does not have an approximation how long each step will take, and more specifically when all the tests will be completed. They cannot communicate an expected completion time to the production line. If a part is high priority enough, a person can be sent to the area to follow the parts as it moves through inspection.

2. Inability to identify bottlenecks in the process

   Since there is no standard process a part follows, management of the area is unable to identify process bottlenecks. There is no tracking of how long a part spends at any of the 200+ stations or how size of the backlog at each station. Potential bottlenecks in the process are only monitored through visual inspection of the package backlog.

3. Masking of root causes that may exist outside of inspection area

   When a part is delayed prior to reaching the production line it is typically blamed on the incoming inspection area. It may be possible, however, that part of this delay is the result of improper part ordering policies from the program office or other external factors. Without data, it is not possible to identify the root causes of the part delay.

4. Low morale and frustration

   The morale in the incoming inspection area tends to be low. The downstream customers are often upset with the area, which is unable to explain why there are part delays. The management of the area feels that they are working as hard as they can to get the parts out there but do not have detailed data to show how good their performance is. This lack of information leads to a high level of frustration between the involved parties.

5.6 Research Goals

To reiterate the research goals as defined in section 1.1, the goals of this project are to:

1. Identify bottlenecks in the inspection process
2. Identify sources of variation in cycle time

3. Provide the ability to easily locate a part in the inspection process

Additionally, this project will expand the use of visual metrics and Lean principles beyond the manufacturing floor into the supply chain.

5.7 Virtual Business Systems (VBS)

In order to meet the objectives of the research goals, the Virtual Business Systems (VBS) platform within the IADC was used. In 2004, the Visual Factory project was renamed to VBS and used to support the facility's Lean transformation. It is a real time metrics project that benefits several customers and end users including Operations, Program Management, and Engineering. Since its founding, the use of Labview to create visual dashboards screens has been embraced by the user community with remarkable success on previous projects.

VBS is part of a larger LIVE (Lean Initiative for Value Excellence) initiative at IADC, which recently was recognized as one of the top 4 Six Sigma projects company wide with the CEO award. In addition, the LIVE initiative was credited with creating increased productivity, resulting in significant cost reductions. These cost reductions were then returned to the customer in the form of a give back, which occurs when actual expenses are less than anticipated.

Prior to the VBS initiative there was minimal real time feedback on the performance of a process at the IADC facility. As is common in many manufacturing environments, process data was collected in a legacy system and reports were generated in batches later in the day or week. Often these reports would not be examined in detail until the end of the month management update meetings. Consequently, the feedback loop to the production process took a very long time and often did not drive performance improvements.

VBS created an infrastructure that enabled a real-time flow of information back to the production line. The main challenge in displaying data real-time was that the raw data was stored in a legacy mainframe, which was designed as a system of record rather than an analytical tool. In collaboration with the Information Technology department, VBS was able to store a copy of the data in a relational database that was designed for analysis purposed. In the database, any number of users could access it through an interface and present the raw data in a meaningful way. Additionally, the data in the database could be updated from the mainframe every 10 minutes, allowing for near real-time process feedback. The VBS team determined the Labview program to be the best means of accessing the database to create visual dashboards. Labview was chosen because of the widespread familiarity with it throughout Raytheon, the ease of programming, and short development time[15].

Figure 5-4 illustrates the relationship between each of the levels of data storage.

---

[15] McCaghren, Neville "Enabling Process Improvements Through Visual Performance Indicators" MIT LFM Thesis, June 2005

Data Tool

- Pulls data out of databases for analysis and display
- Flexible Interface

Relational Database

- Aggregates data
- Allows fast access to data

Mainframe Legacy System

- System of record that creates source data
- Single screen access

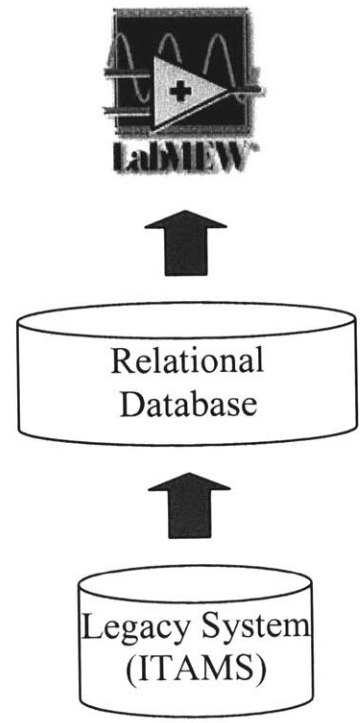


Figure 5-4 - Data Flow at the IADC

VBS has enabled real-time metrics at both the facility and production area level. At the facility level, the visual dashboards display a common set of metrics and goals that all production areas can manage to and be compared against. Previously, it was up to the individual production area to define and measure the metrics they deemed most useful. When the need arises, dashboards for individual production areas can be created as well. As of March 2007, there are 20 LCD monitors that have been deployed across the facility to display VBS dashboards. To further facilitate the deployment of real time metrics across the Lean Enterprise, Raytheon has designed system of autonomous display units consisting of an LCD monitor and a PC. An additional 90 display units will be deployed at facilities in Andover, MA, Portsmouth, RI, Keyport, WA, and McKinney, TX.

The following is a list of facility wide metrics and representative metrics from production areas:

- Work In Process Turns
- Production Lead Time
- Value Added per Employee
- Total Employee Involvement

5.8 Previous Research Completed at the IADC

Much of the work performed for this research is related to work done by Neville McCagharen in an LFM internship from June to December 2004. Neville worked within the Microwave component manufacturing value stream to identify and develop the proper metrics and targets to meet specified performance goals. He then used the VBS tools to collect data and display these metrics throughout the area. This work demonstrated to the facility how the use of real-time metrics could improve process performance.

Shortly after the end of Neville's project, the facility underwent a Lean assessment in which each value stream was rated on how well it had adopted Lean principles. In turn, the value stream was then responsible for creating a plan to make the area more Lean. Visual metrics were created and rolled out throughout the IADC to support this Lean transition. These efforts familiarized the facility with visual metrics and built support with plant management, making the introduction of new metrics to the Incoming Inspection much easier.

Also taking place from June to December 2004, Ronak Shah (LFM 2005) completed an internship at the IADC related to the use of RFID technology. The promise of RFID technology is better tracking of inventory throughout an entire process. However, based on the low volume of parts and high IT costs required for implementation, Ronak concluded that it was best to delay adoption of RFID at the IADC. As part of the internship he created a decision model to help Raytheon determine when the facility would be ready for RFID adoption.

5.9 VBS Dashboards

There are multiple options available to meet the research goals. Prior to this project, no attempts had been made to create readily available metrics or a faster method of accessing and understanding area performance. It was important to confirm that the creation of VBS dashboards would be the most effective method of improving the visibility of the area. The benefits of using the VBS infrastructure are as follows:

1. Facility familiarity with VBS dashboards – The VBS dashboards had been present in the manufacturing areas for greater than two years at the time of the project. By extending the use of visual dashboards into a non-manufacturing area the researcher could test the overall receptiveness of other groups to these tools.

2. Scalability – Metrics for the MV&T area can be displayed on as many or as few screens as desired throughout the facility. Individuals with a VBS dashboard program installed on their computer can access the metrics as well.

3. Ability to display metrics visually – Labview is designed to display information graphically. It contains many standard features that allow users to understand historical trends other data easily.

4. Ease of update – There is substantial Labview knowledge within the VBS team. As the facility becomes more familiar with VBS this knowledge base will expand and there will be additional Labview users able to update the dashboards created.

The main alternatives considered to using VBS and Labview were the creation of Microsoft Access automated reports and an IT generated daily report. Each of these methods could consolidate data into a single consolidated report. However, this information would be located within a single file and would require additional manipulation to create, print, and post a graph. These methods would require a major user commitment and would most likely result in generated reports that were only used occasionally. On the other hand, once the VBS dashboard was completed it could be displayed on a computer monitor where anyone entering the area can easily see how the area is performing.

Labview requires data to be present in a relational database so that it can access and display it. As indicated previously, the mainframe system cannot be accessed by an external software package easily. Rather, a project was initiated with the Information Technology department to create a copy of the data stored in the mainframe within the Oracle relational database. In this process, a program is written in the mainframe to extract the raw data into a text flat file. This program is currently updated on a daily basis but can be increased to update hourly. The file is then loaded into an Oracle table that has been designed to accept the flat file. The table contains multiple indexes and is optimized to allow for fast access by the Labview program.

Because of testing requirements, the IT project was not finished at the end of the research project. A feed containing production data was not available. However, the researcher had access to a test environment that contained data current as of November 15. This provided sufficient data to fully demonstrate the dashboards and accept inputs from area management. The dashboards were designed in a way that it could easily incorporate production data once the IT project was fully completed.

5.9.1 Summary Metrics

The first dashboard created contained Summary Metrics for the overall MV&T. The goal of this dashboard was to create a sense of baseline metrics that could be used to track area performance over time and present them to the user in an easily understood format. Prior to this dashboard there was no method to clearly quantify how the area was performing outside of visually estimating how many packages were awaiting inspection. The researcher worked closely with the MV&T management to understand what metrics best represent the performance of the area.

The selection of metrics required careful consideration because they would drive certain behaviors. For instance, the use of a mean vs median cycle time displays related, but decidedly different information. The use of the mean cycle time captures the performance of an entire group of packages. However, if certain packages are taking an uncharacteristically long time in inspection then the mean cycle time can be high even though the rest of the packages were processed in a timely manner. If packages continue to remain in inspection then the average time will increase as time passes. This change in average time will making it difficult to compare recent performance with historical trends until all of the packages exit the area. In order to solve this weighting of long cycle time packages the use of the median is considered. By tracking how long it takes the 50th percentile package to exit the area, comparative data can be collected within a few days rather than weeks or months. However, tracking only the mean would not capture what happens beyond the 50th percentile package and long cycle time packages would be lost. If an area only had goals based on the median then it could be inclined to quickly inspect a group of packages until it completes half of them and then move onto the next group, leaving the remaining packages for a later time. To balance these two needs, both metrics were included in the dashboards.

The Summary Metrics dashboard contains multiple tabs that each display information about the performance of the overall area and workstations within the area. The program can automatically cycle between tabs to display all relevant metrics. The tabs contained in the dashboard are Weekly, Daily, Histogram, and Bucket Backlog. The next sections describe each of these tabs.

5.9.2 Weekly and Daily Tabs

The Weekly and Daily tabs display historical trends of performance over time for the entire MV&T inspection area. The Weekly tab groups incoming packages received into weekly groups and displays the previous 52 weeks of performance. The Daily tab groups incoming packages into groups by day received and displays data from the previous 60 days. In combination, the user can understand how performance changes over the course of the year, such as seasonality, or can focus on any changes that occur in the short term.

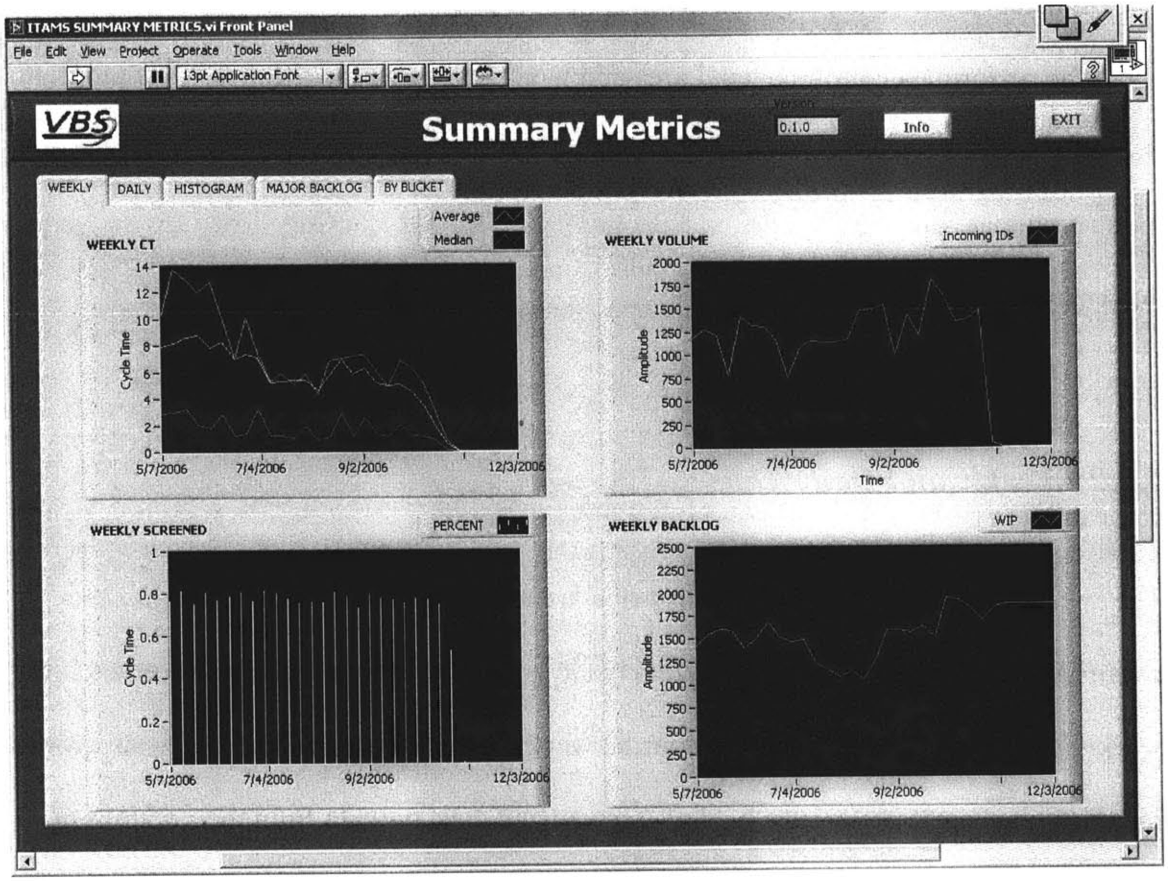


Figure 5-5 - Summary Metrics (Weekly Tab)

The Summary Metrics Weekly Tab is displayed in Figure 5-5. The Weekly and Daily tabs contain the same following metrics:

- Cycle Time – The cycle time for the area is defined from the point the package is received into the inspection area until it exits for inventory stores or the production floor. This is the first time area management has had the ability to track a performance through the entire area. The mean and median cycle times are each displayed on the graph. Additionally, code for quartiles was included but not turned on to simplify the display.

- Volume – The number of parts received during a daily or weekly time period. There is seasonality associated with the ordering of component parts and raw materials, varying the volume of parts received over time. This graph shows the seasonality and will help the area management to plan accordingly.
- Screened Percentage – The volume of parts that are inspected at the facility. As of December 2006, approximately 80% of packages were inspected on site. The remaining 20% were inspected at the supplier and are immediately sent to inventory stores, resulting in a cycle time of 0. Since all packages are included in the median and mean cycle time metrics, the average cycle time will vary as this number changes.
- Backlog – This is the number of packages that are in the area awaiting inspection at the end of the time period. This metric replaces visual inspection as a means of understanding how many packages are in the overall inspection area. Area management can choose to increase or decrease labor through overtime based on the backlog of the area.

5.9.3 Histogram

While the average and median cycle times contain valuable information, the aggregation of data into single points masks the distribution of cycle times. As evidenced by its name, the Histogram tab contains a histogram of the cycle times for the overall inspection area and individual stations (also referred to as "Buckets") over a specified period of time. This allows the user to understand what portion of packages move quickly though the area, i.e. less than a day, in comparison to the packages that require over 10 days. Figure 5-6 contains the Histogram Tab for Summary Metrics.

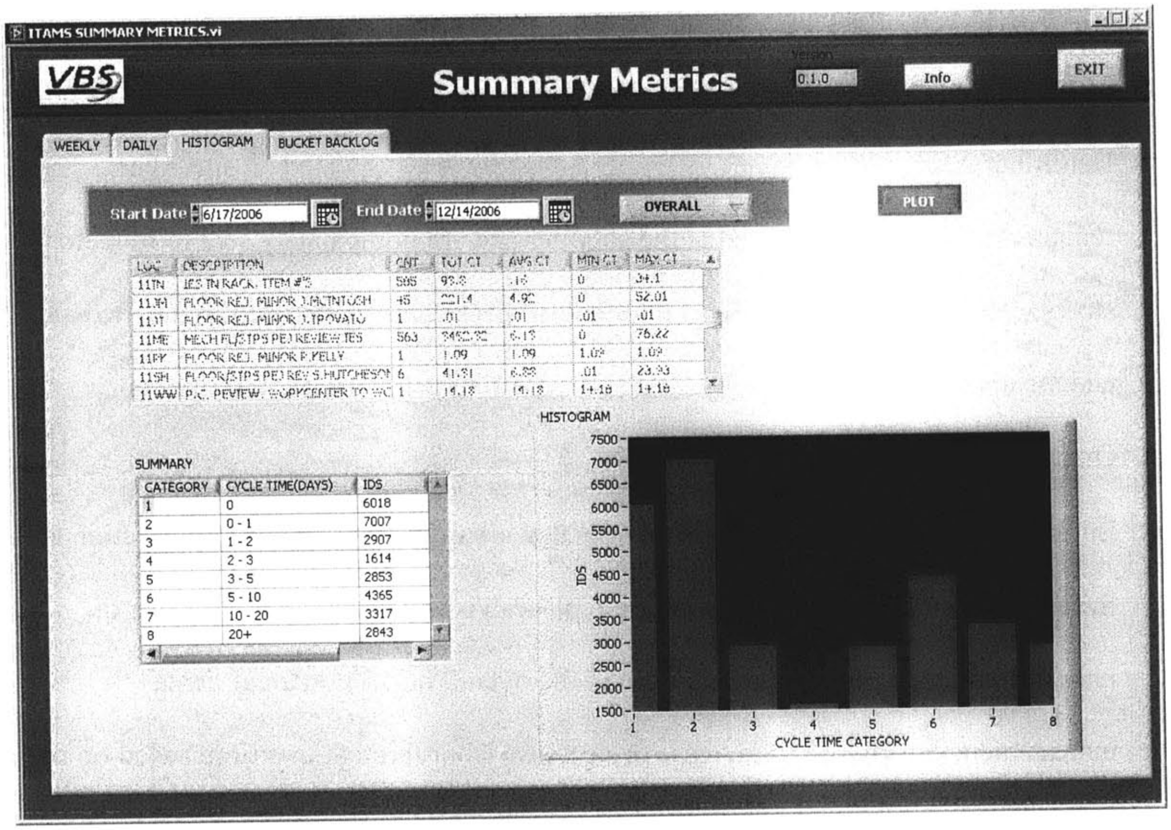


Figure 5-6 - Summary Metrics (Histogram Tab)

MV&T managers explored the possibility of committing to a three-day cycle for all parts entering the area. This three-day timeframe was decided because the overall time through the area was believed to be around five days. However, once the distribution of cycle times through the area was available it was immediately apparent that committing to this three-day cycle time was not practical. The distribution of cycle times clustered with over 40% of the packages requiring less than one day with a very long tail, with 20% of the packages remaining in the area for 10 days or more. This variation in cycle times arises from different testing requirements for each part. As such, there should be different cycle time goals according to the testing requirements rather than setting a single unattainable goal. The ability to observe the significant variation in cycle times illustrates the need to understand what tests and procedures result in a package remaining in the area for a given amount of time, in this case that could be over 10 days.

When the histogram for an individual station is selected, additional metrics for bottleneck analysis are displayed. The metrics displayed are the number of packages that enter an inspection station, the average cycle time for each inspection, the minimum and maximum cycle times, and the total inspection time for all packages. These metrics will identify what steps in the inspection process take the most time so that management can focus efforts on reducing the cycle time for that station. The number of packages entering an inspection station is useful because it helps illustrate the level of impact improving the performance of a station will have. For instance, if a station has a very long cycle time but only a few packages move through the station then time spent improving the cycle time for that area will not have as much of an impact as time spent improving a station with a very high volume and an average cycle time. This bottleneck analysis was not possible prior to these metrics.

5.9.4 Part Locator (ITAMS Aging Tool)

While the Summary Metrics dashboard captures the performance of the overall inspection area, the Part Locator dashboard details the performance of individual inspection stations (or buckets). The Part Locator is designed to track how many parts are present at a station and provide a point and click mechanism to obtain package level information. By tracking individual packages, an average cycle time can be calculated for each station, which may be useful to help customers anticipate when their package should leave that inspection station.

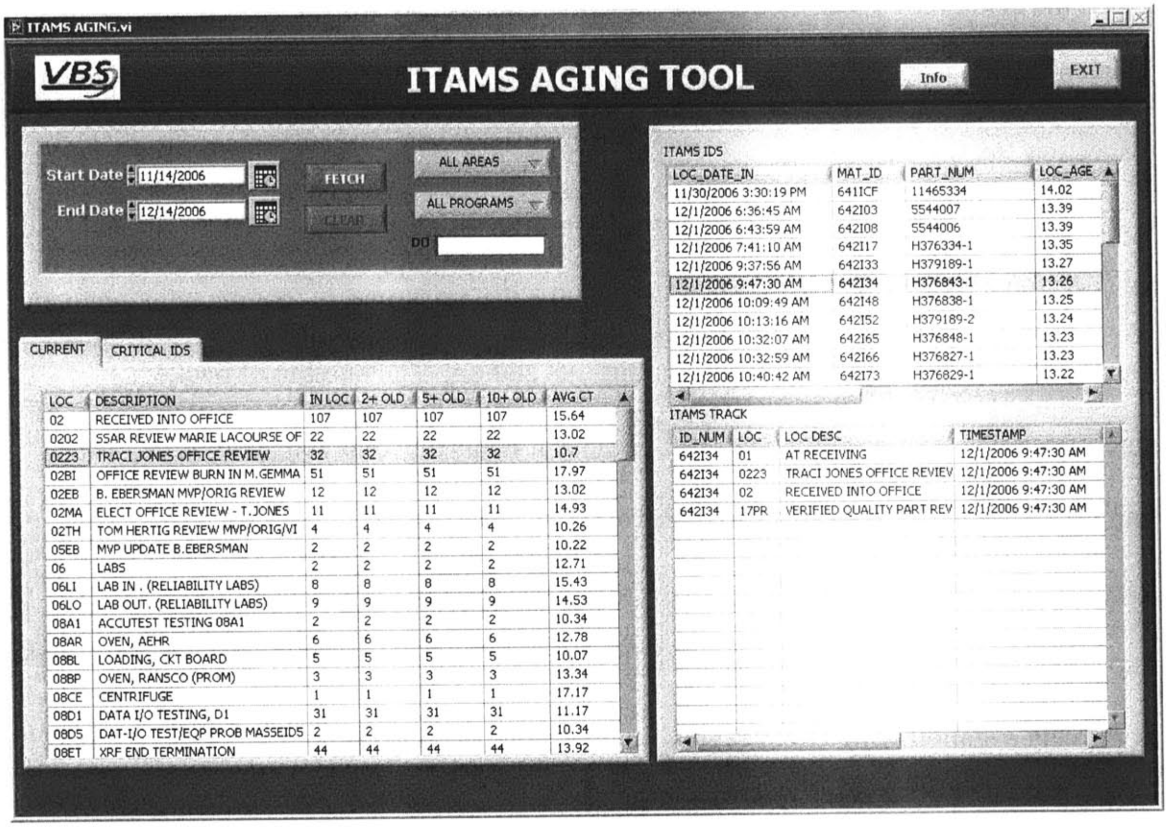


Figure 5-7 - Part Locator

Refer to Figure 5-7 for a screenshot of the Part Locator dashboard. There are three main sections of the dashboard, each providing a different level of detail:

- Location Summary – This table lists every station that contains a package, along with the number of packages in the location, the number of packages that have been there 2 days, 5 days, and 10 days, and the average cycle time for that station. Once a station is selected, the ITAMS IDs table is populated.

- ITAMS IDs – Contains a list of every package present in a station, ordered by the time it has been at that station. This gives management the opportunity to focus on ensuring no package remains in an area for too long. When a package ID is selected, the ITAMS Track(ing) table is populated.
- ITAMS Track – This is the history of a package ID in the inspection area, ordered by timestamp at each inspection station.

After management of the MV&T area, the secondary customers for this tool are the program management teams and downstream production areas. Often, a person responsible for material ordering in the program office will manually follow a part as it moves through the inspection process. This requires someone to logon to ITAMS mainframe and look up a part one by one. This is a very time consuming and repetitive process and does not give an overall view of the inspection area. The main advantage of this dashboard is the reduction in the amount of time required to track parts. The material handler can enter the program code into the DO entry space and is able to track only the material for a given program. When there can be hundreds of parts in the inspection process for a program, the material handler can track all the parts in minutes rather than hours.

The Critical IDS tab displays the current list of packages that are marked for expediting through the area. When a package ID on the list is selected, the location history for the package is displayed in the ITAMS Track table.

5.9.5 Escalation Process

The final visual dashboard created to drive intended performance was the Escalation Board, which was in the test phase as of December 2006. In this process, when an event occurs that has the potential to, or has already, shut down the production line an escalation is initiated. The Escalation Board is analogous to an Andon cord, but is designed for use outside of the manufacturing floor. Pulling the Andon cord shuts down a manufacturing line and focuses the entire efforts of the team at rectifying the situation. Initiating an escalation identifies what has the potential to halt the production line and directs a series of alerts and tracks the escalation on a central screen to quickly resolve the issues.

Prior to initiating an escalation alert, an escalation chain is identified. The chain is a list of the people who will be contacted with the escalation in order, along with the number of hours they have to resolve the issue. When an escalation reaches a person then either an e-mail will be sent or a pop-up will appear on their computer screen alerting them that there is a critical issue that must be resolved. If a person does not respond to the escalation or is unable to fix it, the next person in the chain (presumably someone more senior) will be alerted. An escalation has the potential to reach the plant manager if it is not resolved quickly enough.

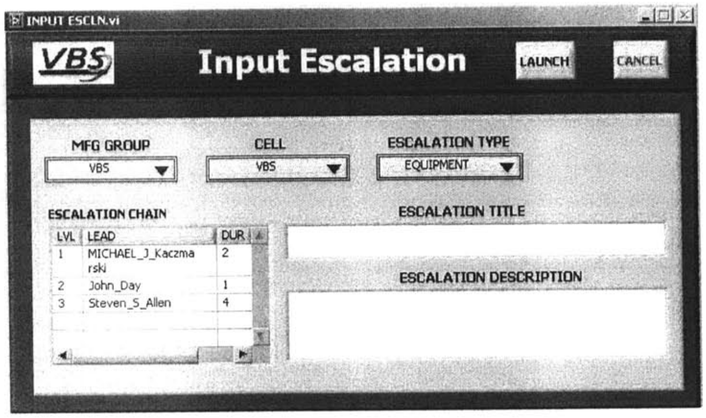


Figure 5-8 - Escalation Input Screen

Figure 5-8 displays the input screen to initiate an escalation. In this screen the manufacturing group, cell, and type of escalation is selected and then the escalation chain is displayed. For instance, a machine malfunction is an equipment escalation. A supply chain escalation may occur when a production line is close to running out of a part or already has run out of a part. The user initiating the escalation then enters an escalation title and description and selects the Launch button.

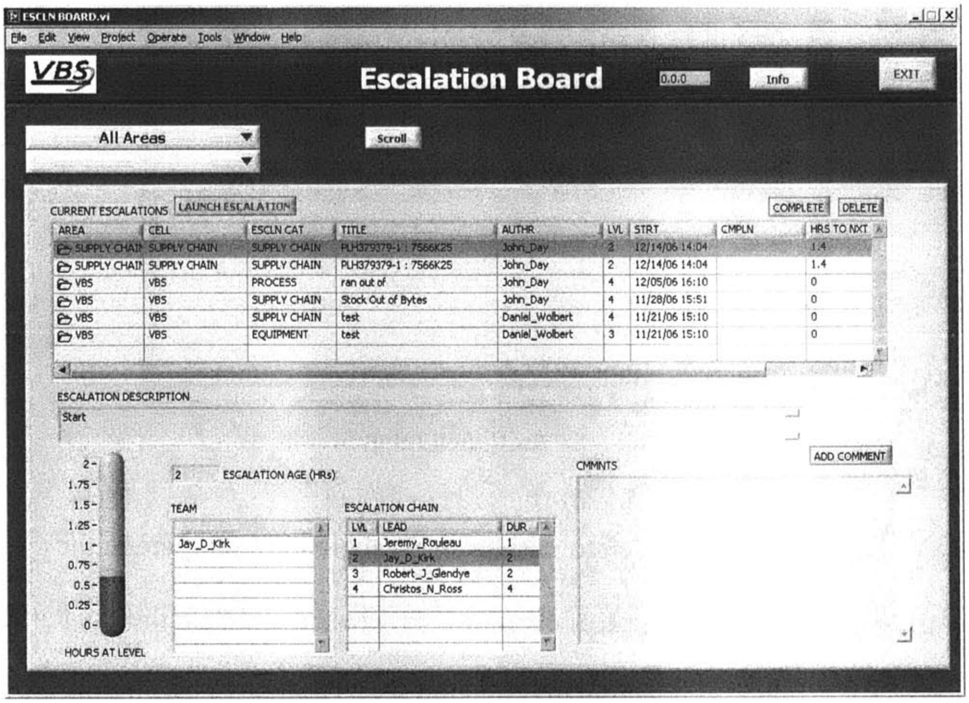


Figure 5-9 - Escalation Board

Once an escalation is initiated it appears on the Escalation Board (Figure 5-9). The Escalation Board is displayed periodically across the facility and contains all of the escalations occurring at a given time. It allows everyone in the facility to understand what the highest priority issues area so that efforts can be made to resolve these issues. In this sense the goal of the Escalation Board is similar to the goal of an Andon cord.

Also similar to an Andon cord, the potential introduction of this process has been met with resistance from those it will track. While the overall goal of the process is to resolve critical issues as quickly as possible, several people who would be directly impacted by this board remarked that it was an additional method of tracking people. The major proponents of this process were the plant management and manufacturing area leaders.

Their goal is to keep the production line running and they are interested in using any tool available to focus the efforts of people.

The challenge going forward is creating a process that works within the Raytheon culture and is seen as a valuable tool. Whenever a new change is introduced into an established group, it is natural and expected that it be met with resistance. Even a small change can be seen as a threat to the organizational power structure that exists in the status quo. De Feo and Barnard[16] listed "Rules of the Road" in order to successfully overcome resistance to change, several of which are listed below:

- Secure the active participation in those who will be affected
- Provide sufficient time for those affected to come to terms with the change
- Be transparent with the change
- Gradually introduce the change
- Treat people with dignity

The overall theme in these rules is to work those affected by the change so that they understand why this change is occurring. Ironically, many of the people who would be resistant to the Escalation Board would have been proponents of implementing Andon cords for production line workers.

[16] De Feo, Joseph and Barnard, William, "Juran Institute's Six Sigma Breakthrough and Beyond", pp277-278, McGraw-Hill, 2004

6 Recommendations and Conclusions

6.1 Recommendations

Although the IADC facility has already traveled far along on its Lean transformation, in the spirit of continuous improvement, plant management recognizes that it must continue to work aggressively to become Lean. The following is a list of recommendations for the entire IADC facility and the Incoming Inspection area:

Facility-Wide:

Continue Expanding Lean throughout Facility

The Lean implementation has experienced remarkable success in the short time since it began. Workers are engaged and working with management to implement Lean practices. However, most of the effort has been focused on the manufacturing floor; this was a logical starting point that produced tangible results. Now that the manufacturing floor has experienced much of the difficult transition to Lean, it will be able to continue to sustain this transition.

Going forward, an emphasis must be placed on making upstream processes and other functions Lean. This thesis explored applying Lean metrics into a supply chain function, which was one of the first attempts at introducing Lean principles into the supply chain area. Raytheon must continue to examine both its internal and external supply chains to make them more Lean. Additionally, the program offices can examine their processes to identify waste within the system that can be eliminated. As Lean concepts are moved beyond the production line, Raytheon will be able to transform itself into a Lean enterprise.

Create Expert Data Users

There is a tremendous amount of data collected each day throughout the IADC. However, much of this data is collected for archival purposes and is never reviewed or turned into information. Knowledge of this data is constrained to a small group within the facility that is well versed in the tools to access the data and actively seek to understand what data is available and how it can be used. The majority of people are unaware of what information is available and can be accessed easily and quickly. Additionally, the users of the data typically access it on an as- needed basis. As a result, users must often spend time relearning how to use the data and knowledge is often lost as people move between positions.

The creation of expert data users responsible primarily for understanding and communicating what data is available and training people on how to most effectively use it will help solve this problem. The experts will also be responsible for documenting data to help in later knowledge transfer. This will expand the use of data to additional users throughout the facility in a sustainable way. As additional people become familiar with the data available, the use of data will become pervasive throughout the entire IADC.

Establish a Data Strategy

The current data infrastructure at the IADC is managed by the IT department and has arisen over time based on the needs of individuals or groups to complete specific tasks. This piece-meal approach results in projects being independently designed to improve the data infrastructure and a less than optimal use of resources. Going forward, as data plays a more important role in the facility, a strategy must be established around what data must be collected, the owners of that data, and who uses it. A recommended division of ownership is that the IT department is responsible for presenting and maintaining the data while the business users are responsible for determining *what* data is collected and *how* it is presented. This strategy will create a holistic effort to identify the ideal data infrastructure for the entire facility.

Incoming Inspection Area Recommendations:

Stabilize the Inspection Process

The current inspection process has a highly variable cycle time. The overall system should be examined for possible ways to make the process more consistent through incremental improvements or entire process reengineering. The visual dashboards will help in identifying these methods. However, it will take time and considerable effort to reduce the variability in the system. Once the process has been stabilized it can then in turn be improved. Additionally, customers will then be able to have reliable estimates when their part will be available, alleviating some of the major concerns with the area.

Reduce the Backlog of Material in Incoming Inspection

At any given time, there is several days worth of inventory waiting processing in the incoming inspection area. Apart from the financial benefits of reducing the carrying costs for this inventory, there are the process efficiencies to be gained through this reduction. Once the backlog has been reduced, the impact of ordering and staffing policies on creating the backlog can be examined. It will become more apparent if the increase in orders placed at the end of a quarter are causing the backlog and process changes can be implemented to avoid this backlog in the future.

Standardize Part Flow Through the Inspection Area

With the different testing requirements specified by the design engineering, any given parts entering the incoming inspection process may follow one of hundreds to thousands of different paths. As such, it is not visually apparent where a part is in its inspection process and when it will become available. By creating a more standardized flow through the area it will help workers and managers to track performance visually and reduce wasted motions moving packages across a wide range of work stations.

6.2 Conclusions

Although it was not possible to collect results based on the implementation timelines, as future continuous improvement projects are implemented clear process improvement goals can be set. Prior to the project, a package remained in the incoming inspection area on average between 4-6 days depending on staffing levels and incoming volume. An increase in cycle time through the area of 25 or 50% would not only make the package available sooner, but it would also decrease the inventory backlog in accordance with Little's Law (Number of units in a system = Arrival Rate x Time in system). While the value of each package has not been disclosed for confidentiality reasons, Figure 6-1 lists the annual holding cost savings (assuming a 10% carrying cost and a backlog of 1500 packages) for different values and backlog reduction percentages.

Value of Each Package	Value of Inventory Backlog	Annual Holding Cost	Savings From Backlog Reduction	
			25%	50%
$100	$150,000	$15,000	$3,750	$7,500
$1,000	$1,500,000	$150,000	$37,500	$75,000
$10,000	$15,000,000	$1,500,000	$375,000	$750,000

Figure 6-1 - Savings From Backlog Reduction

Raytheon's Integrated Air Defense Center has experienced a great deal of success since it embarked on its Lean journey. This success has helped position the entire Integrated Defense Systems division to remain competitive and continue to grow its business in the face of government cutbacks. While it has been a difficult process, the facility leadership remains committed to improving plant efficiencies. The use of visual metrics in recent years has helped to enable this Lean transformation on the production line. The project completed for this thesis has expanded this valuable tool to the incoming inspection area. These visual dashboards have created a standardized set of performance measurements for the area that can be used as a platform for future continuous improvement projects.

The defense industry has experienced tremendous change in a period of less than twenty years. Gone are they days when the customer (the US Government) was willing to pay any price for the most technologically advanced weapons. Now the emphasis is on efficient production and reducing waste in the process through Lean principles. However, the industry must balance the desire to transition to Lean with legacy incentives that remain that reward actions contrary to Lean.

Appendix A – VBS Copyright

The following copyright pertains to the information related to the Virtual Business Systems.

 5111-57