LEAN TRANSFORMATION IN AEROSPACE ASSEMBLY OPERATIONS

by

Douglas H. Frauenberger

B.S. Naval Architecture and Marine Engineering, Webb Institute, 2002

Submitted to the Sloan School of Management and the
Department of Mechanical Engineering
in Partial Fulfillment of the Requirements for the Degrees of

Master of Business Administration
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Master of Science in Ocean Systems Management

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Signature of Author ______________________________________
May 11, 2007
MIT Sloan School of Management
Department of Mechanical Engineering, Center for Ocean Engineering

Certified by ______________________________________
Janice A. Klein, Thesis Advisor
Sloan School of Management

Certified by ______________________________________
David Hardt, Thesis Advisor
Ralph E. & Elaine F. Cross Professor of Mechanical Engineering
School of Mechanical Engineering

Accepted by ______________________________________
Henry S. Marcus
Professor of Mechanical Engineering, Marine Systems

Accepted by ______________________________________
Debbie H. Berechman, Executive Director, MBA Program
Sloan School of Management

Accepted by ______________________________________
Professor Lallit Anand, Graduate Committee Chairman
Department of Mechanical Engineering

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ABSTRACT

For the past two decades, virtually all manufacturing companies in the United States have adopted or are in the process of adopting lean manufacturing. Globalization has resulted in the increased availability of reliable, low cost sources putting greater pressures on traditional US manufacturing companies to reduce costs. The need to successfully transform to lean has only grown in importance in this new operating environment, resulting in renewed focus on such initiatives in the United States.

This thesis discusses various approaches to lean manufacturing with reference to specific examples from both academia and industry. In particular, lean transformation efforts in Mitchell Engine Company's* Final Assembly Plant will be provided as a case study. Focus on the JP-3525 fan case assembly cell provides specific examples on how shop floor improvements, assembly cell redesign, and flow can improve process cycle time and decrease variability. The direct result of this work has been a 15% decrease in cycle time and a 100% decrease in variability in the JP-3525 fan case assembly cell.

Finally, the role front-line supervisors play in change initiatives will be introduced, discussing the position from both management and labor perspectives. Based on past research, recommendations will be made on how to improve cell leader effectiveness, recognizing these changes require systemic change within the organization.

Thesis Supervisor: Janice A. Klein
Title: Senior Lecturer, Sloan School of Management

Thesis Supervisor: David Hardt
Title: Ralph E. & Elaine F. Cross Professor of Mechanical Engineering

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* Company Name and associated information is masked.

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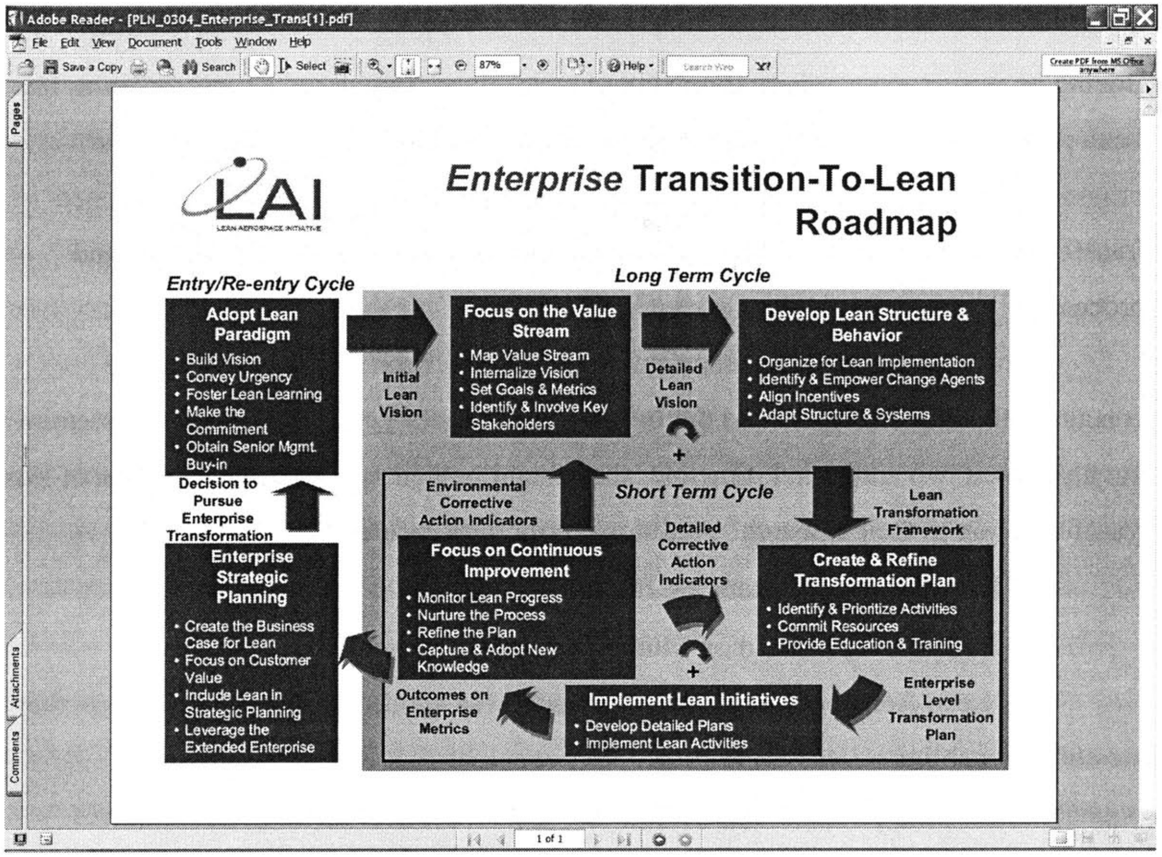

Figure 1 – LAI Transition-To-Lean Roadmap[12]

2.4 Industry Approaches to Lean Manufacturing

Over the course of the last two decades, lean has made its way into a number of manufacturing organizations in the United States. There is no question that many associate lean with automotive manufacturing first and foremost, and most of the data supporting lean defaults to its success in the automotive industry. There have been significant efforts in other industries as well.

This section will discuss various industry approaches to lean transformation and attempt to distinguish which key elements are essential for success across all industries. Particular attention will be placed on assembly operations, which are significantly different than machining operations, and have more relevance to the Mitchell Engine Company fan case assembly operations that will be discussed later.

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[12] Lean Aerospace Initiative Website:
http://Lean.mit.edu/index.php?option=com_docman&task=cat_view&Itemid=99999999&gid=127

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Chapter 1: Introduction

1.1 Introduction

Virtually all large manufacturing organizations in the United States have adopted lean manufacturing methods or have plans to do so. Lean as it is known today was defined 50 years ago by operations at the Toyota Motor Corporation. While many companies have successfully used lean transformation to redefine their operations, many still struggle to match Toyota's operations excellence, arguably the most successful and best managed manufacturing organization in the world.

The success of the Toyota Production System inspired various academic groups to study the system, providing recommendations on how to successfully implement the principles of lean manufacturing. On the heels of such research, organizations in the United States began to define their own approaches to lean transformation. General Motors, for example, partnered with Toyota in a California plant in the hopes that working directly with the experts would enable the company and culture to see, understand, and be inspired by the principles of lean. Other organizations developed unique operating systems with lean at their core, designed to tailor lean manufacturing to their own company. Much time and effort has been put in to defining, developing, implementing, and modifying these operating systems in an attempt to realize the productivity benefits of the Toyota Production System.

A discussion of lean transformations is contained within this thesis, highlighting academic approaches to lean implementation and discussing key concepts, principles, and approaches from various industries. A case study on lean transformation at Mitchell Engine Company's* assembly operations is discussed using the tools of the LEAN operating system. This focus on efforts at Mitchell Engine Company is intended to provide the reader some insight to both enablers and barriers to success, as experienced in aerospace assembly operations. It is expected that the experience described within will be applicable and transferable to other industries realizing that the environment at Mitchell Engine Company mirrors that of many large, established manufacturing corporations in the United States. With increasing pressures in the global marketplace,

* Company name and associated information is masked throughout the thesis.

the success of such companies is tied directly to their ability to improve their operations through company-wide lean transformation efforts.

1.2 Thesis Outline

Chapter 2 of this thesis provides an introduction to lean manufacturing and its beginnings in the United States. Lean manufacturing across various industries is discussed focusing on key principles, concepts, and approaches to implementation.

Chapter 3 provides the reader with a history of lean manufacturing efforts at Mitchell Engine Company and introduces the LEAN operating system.

Chapter 4 gives background on Mitchell Engine Company's Final Assembly Plant and provides an introduction to jet engine operation and assembly. The JP-3525 fan case assembly cell is introduced and specific aspects of the lean transformation with regards to this cell will be discussed. Accomplishments, results, and challenges of the project are provided.

Chapter 5 provides an organizational analysis using Three Lenses. Specific attention will be placed on the role of the first line supervisor in change initiatives with recommendations made on how to improve the effectiveness of the position.

Chapter 6 draws a conclusion for the work, discusses it applicability to other industries as well as recommendations for remaining research.

Chapter 2: Lean Manufacturing

2.1 Origins of Lean Manufacturing

The origins of lean manufacturing principles as they are understood today can be traced back to industry evolutions dating back to the 1800's. Jonathan Rheaume, LFM '03 does a particularly thorough job of outlining these principles in his thesis "High-Mix, Low Volume Lean Manufacturing Implementation and Lot Size Optimization at an Aerospace OEM"[1]. In particular, he calls reference to "The Evolution of Manufacturing Control – What Has Been, What Will Be" written by Kenneth N. McKay. In this paper, McKay identifies numerous modern manufacturing techniques and ties them to their historical roots. The list below outlines these techniques and dates their reference: [2]

- Cloning of factories – 1800's
- Design for Manufacture – 1830's
- Treatment of downstream departments as customers – 1910's
- Focus on inefficiency and waste – 1910's
- Sampling and quality control – 1920's
- Pull of material through factory – 1920's
- Flow lines – 1920's
- Just-In-Time Manufacturing – 1920's
- Supply Chain Management – 1920's
- Co-location of horizontal elements of supply chain – 1930's
- Link between remuneration and productivity – 1930's
- Identifying and working out bottlenecks – 1940's

These concepts had been adopted in the days of mass production to clearly distinguish the capabilities of Western societies in the early 1900's through the era of World War II. Each idea was innovative in its own right, allowing incremental gains at the time of their conception within the mass production model. However it was the foresight of Taiichi

[1] Jonathan M. Rheaume, "High-Mix, Low Volume Lean Manufacturing Implementation and Lot Size Optimization at an Aerospace OEM", (Masters Thesis, Massachusetts Institute of Technology, 2003)
[2] Kenneth N. McKay, "The Evolution of Manufacturing Control – What Has Been, What Will Be", (working paper 03-200), 9-10

Ohno to combine all these concepts and create a system which is known today as the Toyota Production System.

While US automobile manufactures reaped the benefits of huge profits through the 1950's, fledgling Toyota Motor Company was struggling to copy the US model. Faced with a domestic market demanding highly variable vehicles in low volumes, tough competition, greater worker involvement, with operations in a war-ravaged capital starved economy, Eiji Toyoda and Taiichi Ohno soon concluded that mass production could never work in Japan.[3] Their solution marks the beginnings of "lean production", a system which over time has been improved upon to address the business challenges faced in a global marketplace.

2.2 Lean Manufacturing Principles

Lean production focuses on reducing operational costs by identifying and eliminating waste in processes. Waste is defined specifically as any human activity which absorbs resources but creates no value.[4] A lean production does more and more with less and less.[5] While less can be translated in many ways – less workers, less space, less inventory, the end goal is a system that is comprised of only "value added" operations. A key to successfully running a lean operation is in the involvement of all employees in the process of identifying and eliminating inefficiencies throughout the organization.

2.2.1 Lean Hits the United States

It wasn't until the OPEC oil crisis of the 1970's when the then mature automobile manufactures in the US realized they needed to adjust their business practices. Still very much "mass producers" they began to realize the opportunity for production improvement through lean manufacturing but found the necessary change extremely difficult. One of the groups that paid particular attention to the Toyota Production System was made up of Daniel Jones, James Womack, and Daniel Roos as part of the

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[3] James P. Womack, Daniel T. Jones, and Danies Roos, The Machine that Changed the World, (New York: Harper Perennial, 1991), 49-50
[4] James P. Womack and Daniel T. Jones. Lean Thinking, (New York: Free Press, 2003), 15
[5] James P. Womack and Daniel T. Jones. Lean Thinking, (New York: Free Press, 2003), 9

MIT International Motor Vehicle Program. Their first publication, The Machine that Changed the World presented a wealth of benchmarking data to show that there is a better way to organize and manage customer relations, the supply chain, product development, and production operations.[6]

Having successfully presented the data that answers the question "why lean" in The Machine that Changed the World, Womack and Jones went on their own and published a second book Lean Thinking. In this publication, Womack and Jones attempt to answer the question "how lean" by identifying principles US manufacturers, operations leaders, manufacturing managers and all those trying to realize the benefits of lean manufacturing could use to guide their actions. The principles outlined in Lean Thinking are[7]:

- Specify Value: the ability to provide a customer with a specific product, at a specific price, when the customer needs it.
- Identify the Value Stream: determine the specific actions required to bring a specific product through the three critical business management tasks: problem solving, information management, and transformation.
- Flow: continuous movement of all activities to design, order and provide product
- Pull: providing a specific product to the customer when needed as opposed to pushing unwanted products onto the customer
- Perfection: the continuous improvement of operations which enhance value, the value stream, flow, and pull.

The transformation from mass production to lean production on the factory floor provides significant benefits to manufacturing organizations. In the companies they studied, Womack and Jones quantify their findings in Lean Thinking, breaking down their findings into two columns. "Initial Lean Conversion" shows the improvements from the initial change from "mass" to "lean", while "Continuous Improvement" shows additional improvements expected from lean efforts over the first 3 years. Although they have not been validated, the improvements are significant, as can be seen in Table 1 below.

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[6] James P. Womack and Daniel T. Jones. Lean Thinking, (New York: Free Press, 2003), 9
[7] James P. Womack and Daniel T. Jones. Lean Thinking, (New York: Free Press, 2003), 15-28

Measure	Initial Lean Conversion	Continuous Improvement
Labor Productivity	Double	Double Again
Production Throughput Times	90% decrease	50% decrease
Inventories (Throughput)	90% decrease	50% decrease
Errors Reaching Customers (Quality)	50% decrease	50% decrease
Scrap (Quality)	50% decrease	50% decrease
Shop floor injuries	50% decrease	50% decrease
Time to Market, New Product	50% decrease	50% decrease

Table 1: Lean Improvements[8]

Many of these measures directly relate to the shop floor, and lean as it was understood through the 1980's and early 1990's was solely understood as a factory floor initiative. However, if a "lean system" is in place it must have roots throughout the entire organization. The shop floor is supported by numerous departments within the organization; engineering, finance, and procurement, as examples. It is essential to take an enterprise view of lean manufacturing, ensuring all aspects of the organization are committed to the same performance metrics, defining success at the enterprise level instead of the departmental level. Great opportunities would be missed if the application of lean principles and practices were confined to the factory floor. Lean thinking can and should be applied to all functions in the enterprise.[9] Perhaps the greatest challenge of transforming to lean is the organizational effort required to change the entire culture of a company.

2.3 Lean Aerospace Initiative

Having witnessed the benefits of lean principles in the Toyota Production System, the US aerospace industry saw an opportunity to benefit from the application of lean principles. In 1993, leaders from the US Air Force in conjunction with MIT, labor

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[8] James P. Womack and Daniel T. Jones. Lean Thinking, (New York: Free Press, 2003), 27

[9] Bozdogan, et. al. "Transitioning to a Lean Enterprise: A Guide for Leaders". Vol. I: Executive Overview. Massachusetts Institute of Technology, 2002, 10

unions, and aerospace businesses including Pratt & Whitney, General Electric, and Boeing as well as many others formed the Lean Aircraft Initiative. Known today as the Lean Aerospace Initiative, the organization was formed to "research, develop, and promulgate practices, tools, and knowledge that enable and accelerate the envisioned transformation of the greater United States aerospace enterprise through people and processes."[10]

Through site visits to consortium members, the Lean Aerospace Initiative concurred that the principles laid out in Womack & Jones Lean Thinking were essential but also noted two additional principles they found in their successful observation of lean transformation in their research. Additional principles include:[11]

- Horizontal Organizational Focus
- Relationships Based on Mutual Trust and Commitment

The Lean Aerospace Initiative identified these additional principles because they are core to enabling a Lean Enterprise. They conclude that without a horizontal organizational focus, value stream flow is not possible due to misaligned incentives within traditional organizational silos. Additionally, they stressed trust in relationships as fundamental to lean. These relations include those with a few suppliers, long-term relationships allowing them the opportunity to realize the benefits of lean along with the organization. Additionally, they stress labor-management agreements that promote win-win situations, with the workforce supporting lean implementation and improvement efforts along with the mutual sharing of the benefits that accrue from these activities.

As a tool for its consortium members, the Lean Aerospace Initiative developed a "Top Level Transition-To-Lean Roadmap" which serves as guidance to enterprise level lean implementation. They stress the importance of leadership and direction from the senior management level, which must lead the transition and fully understand, embrace, and commit to a full conversion to lean for any initiative to succeed. The Transition-To-Lean Roadmap can be seen on the following page in figure 1.

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[10] Lean Aerospace Initiative Website:
http://Lean.mit.edu/index.php?option=com_content&task=view&id=18&Itemid=41

[11] Bozdogan, et. al. "Transitioning to a Lean Enterprise: A Guide for Leaders". Vol. I: Executive Overview. Massachusetts Institute of Technology, 2002, 13

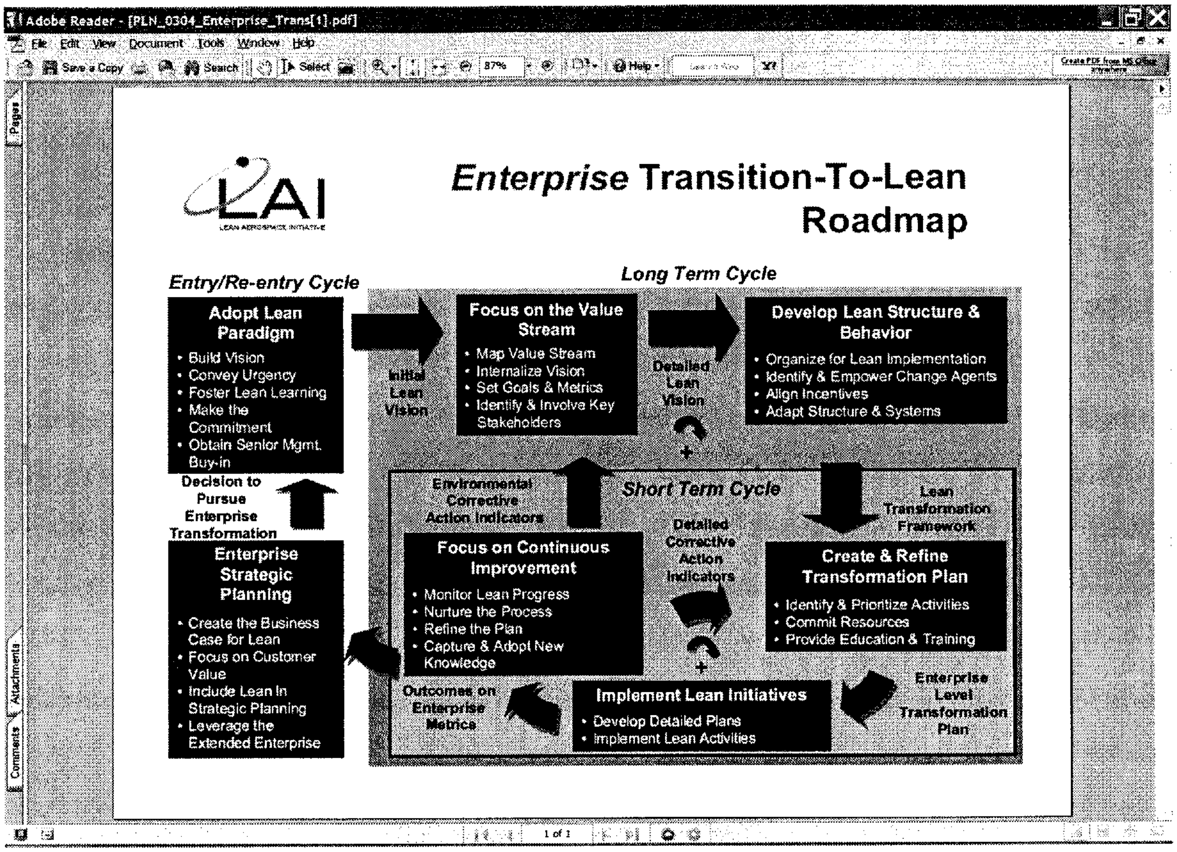

Figure 1 – LAI Transition-To-Lean Roadmap[12]

2.4 Industry Approaches to Lean Manufacturing

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[12] Lean Aerospace Initiative Website:
http://Lean.mit.edu/index.php?option=com_docman&task=cat_view&Itemid=99999999&gid=127

2.4.1 Lean Manufacturing at The Boeing Company

There are a number of past LFM theses that specifically discuss lean implementation at The Boeing Company. In particular, Victoria Gastelum's 2002 thesis titled "Application of Lean Manufacturing Techniques for the Design of the Aircraft Assembly Line" and Vikram Sahney's thesis from 2005 titled "Scheduling and Shop Floor Control in Commercial Aircraft Manufacturing" provide valuable insights to the success' and challenges of lean transformations in aircraft manufacturing.

2.4.1.1 Key Concepts of Lean Manufacturing at Boeing

Aircraft manufacturing is described by Boeing as a steady-stream of interconnecting processes.[13] Boeing's approach to lean is based on the following concepts:

1) Just-In-Time (JIT): by delivering parts only when needed, Boeing benefits from inventory reduction and decreased overall flow time, improving bottom line performance.
2) Jidoka, or error-free production: the prevention of defective parts from flowing downstream in production processes.

2.4.1.2 Principles of Lean Manufacturing at Boeing

Additionally, Boeing believes that there are three key principles to lean: TAKT paced production, one-piece flow, and pull production. According to Gastelum's thesis "These concepts and principles are put into practice by applying a number of techniques such as standardizing work, using visual signals, and defining standard work-in-process to the three principle resources: people, materials, and machinery."[14]

2.4.1.3 Boeing's Approach to Lean Manufacturing

Boeing's ultimate goal is to create moving lines across all of their models, and they offer *The 9 Tactics* as a practical approach to meet this goal. The 9 tactics are used

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[13] Victoria Gastelum, "Applications of Lean Manufacturing Techniques for the Design of the Aircraft Assembly Line", (Masters Thesis, Massachusetts Institute of Technology, 2002). 20
[14] Victoria Gastelum, "Applications of Lean Manufacturing Techniques for the Design of the Aircraft Assembly Line", (Masters Thesis, Massachusetts Institute of Technology, 2002). 19

at Boeing to improve operational efficiency and improve their ability to manage for value. The 9 tactics at Boeing are: [15]

1. Map the value stream
2. Balance the line
3. Standardize work procedures
4. Put visual controls in place
5. Put everything at point of use
6. Establish feeder lines
7. Redesign products and business processes
8. Pulse flow
9. Convert to a moving line

2.4.1.4 Implementation of Lean Manufacturing at Boeing

Lean transformation at Boeing evolves through value-stream mapping and employee empowerment, as discussed by Michelle Bernson in her 2002 thesis titled "The Value of a Common Approach to Lean".[16]

Value Stream Mapping: a tool used to understand and analyze total product flow beginning with raw material on through delivery to the customer.

Employee Empowerment: employees are engaged in lean initiatives at Boeing through involvement in the following activities

- *Accelerated Improvement Workshop's (AIW's)*: these events are the Boeing equivalent of Kaizen events, involving training, planning, and implementation to achieve rapid improvements on the shop floor.
- *Accelerated Maintenance Workshop's (AMW's)*: used by operators and maintenance workers to ensure daily care of critical components and machines.

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[15] "Tactics to Improve Operational Efficiency", Boeing literature, 2002
[16] Michelle Bernson, "The Value of a Common Approach to Lean", (Master's Thesis, Massachusetts Institute of Technology, 2004). 23-24

- *Lean Manufacturing Assessments (LMA's)*: cross-functional assessments which document existing processes, identify improvement opportunities, and develop implementation plans to transform operations from the current to the future improved state.
- *Production, Preparation, Process Workshops (3P)*: workshops that focus on the elimination of waste in process, parts, and equipment through redesign.

2.4.2 Lean Manufacturing in Shipbuilding

Similar to the Lean Aerospace Initiative, the National Shipbuilding Research Program sponsored a Lean Shipbuilding Initiative, founded in 1998. Increasing demand from the industry for information about lean led to its creation, as a way to leverage lean efforts and learning among industry players. Although not seen as a traditional manufacturing setting, shipyards have benefited from the direct application of key lean principles. It is important to understand the unique aspects of shipbuilding and how they affect the industry's approach to lean.

2.4.2.1 Principles of Lean Manufacturing in Shipbuilding

The Lean Shipbuilding Initiative approach focuses on traditional aspects of lean such as flow, pull, and balancing production load. Similar to aircraft manufacturing, shipbuilding can also be defined as a steady stream of interconnecting processes, on a much larger scale. Pre-assemblies flow through job-shops to create sub-assemblies, which flow through production to create blocks, which flow together to build up the ship. Balancing production loads and synchronizing processes is essential to streamlining operations.

2.4.2.2 Approach to Lean Manufacturing in Shipbuilding

Particular attention is paid up-front in the process to design for manufacturability. Shipyards attempt to make each of the block assemblies as standard and repeatable as possible. This goal flows down to the sub-assembly and pre-assembly level as well, resulting in detailed, repeatable, standardized processes. To date, the Lean Shipbuilding Initiative has identified over 500 industry standards currently considered "best practice" which have been shared across industry players, spanning functional departments such as structural, piping systems, HVAC, electrical, and paint. While the benefits of these improvements many not be recognized on the ship currently being built, these standards can be continually built upon on future ship design and production processes.

2.4.2.3 Implementation of Lean Manufacturing in Shipbuilding

Value stream mapping is used consistently throughout the shipbuilding industry as a means to fully coordinate the multiple tiers of synchronized processes that are involved in building a ship.

Yuliya Frenkel, LFM class of 2004, conducted her internship at Northrop Grumman Newport News, focusing on enterprise level value stream mapping for aircraft carriers. She stresses the importance of looking at the value stream on an enterprise level, noting "The needs of the downstream process, as an immediate customer, should be identified at each step of the process keeping in mind the needs of the ship as the internal customer, and the US Navy as the external customer. Value stream identification across the entire enterprise is necessary to identify all the value added steps."[17] Working at the enterprise level is particularly challenging because in addition to the end-use customer, the stakeholders involved in the enterprise include employees, suppliers, shareholders, labor unions, and society; all of which must be addressed to truly achieve successful lean transformation.

In addition to value stream mapping, the principles of continuous flow & pull play important roles in a shipyard, though difficult to implement in a job-shop push mentality. Kaizen events involving all stakeholders are frequently used to promote employee engagement.

2.4.3 Lean Manufacturing at Kodak

In 1998, Kodak decided that it needed to transform to lean operations, forming the Kodak Operating System (KOS). Author Dan McCutcheon explains the history of the

[17] Yuliya M. Frenkel "Enterprise Level Value Stream Mapping and Analysis for Aircraft Carrier Components", (Masters Thesis, Massachusetts Institute of Technology, 2004). 26

KOS in his article "How Kodak Develop its Own Brand of Lean".[18] He notes that some questioned whether the benefits of lean manufacturing would apply to a process-oriented manufacturer like Kodak. The KOS has in fact proven that lean can be applied outside of assembly areas, using the same basic principles.

2.4.3.1 Principles of Lean Manufacturing in the Kodak Operating System

The KOS at its roots can be broken down into the most basic concepts of lean; Just-in-Time, Jidoka, and Heijunka. For Kodak, these principles make up what it refers to as the "House of KOS".

Just-in-Time (JIT): Kodak relates JIT specifically to delivering exactly what the customer needs, when they need it, in the exact amount they need. They strive to do this with as few resources as possible.

Jidoka: a means of ensuring process quality in each process step. By focusing on responding immediately to abnormalities and driving root cause, they can prevent reoccurrence of the problem.

Heijunka: know as leveling production, Kodak focuses on leveling production to the rate of customer demand. Kodak claims this allows them to really drive improvement in their operations.

2.4.3.2 Kodak Operating System Approach to Lean Manufacturing

Kodak uses many of the same manufacturing tools found in the Toyota Production System. These tools include kaizen projects, Six-Sigma studies, value stream mapping, pull systems, kanbans, standardized work, and 5S. In addition they involved their suppliers and customers in the continuous improvement processes, ultimately identifying ways to reduce inventory and do a better job of focusing on activities that are seen as value-added by the customer.

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[18] "How Kodak Developed its own brand of Lean", Advanced Manufacturing, 2003

2.4.3.3 Implementation of the Kodak Operating System

Kodak has adopted a five phase implementation plan, as discussed in Olapeju Popoola's thesis titled "Development of a Methodology for the Rapid Implementation of a Sustainable Lean Manufacturing System".[19] The five lean phases of this plan are:

1) Stability: the focus on creating consistent and capable production where operational performance targets are well defined and can be obtained in a predictable and repeatable manner.

2) Continuous Flow: focus on improving flow between processes by reducing buffers and safety stock.

3) Synchronous Flow: the attempt to pace manufacturing to the customer demand, which is difficult given the significant batch processing performed at Kodak

4) Pull System: performing production of upstream processes based on downstream demand.

5) Production Leveling: focusing on leveling production over time to equal takt time.

Following this work, James Katzen, LFM 2003, worked with Kodak on his thesis titled "Concurrently Designing a Physical Production System and an Information System in a Manufacturing Setting".[20] This thesis focused on the importance of process design in determining manufacturing performance noting that the application of lean principles should be included up front in product and process design. In addition, his thesis discusses the need for companies to concurrently design both information flow and product design flow, and historically information flow is ignored resulting in sub-optimum manufacturing performance. He argues that only by performing the design of the two systems together will process designers ensure the resulting system yields as seamless flow of information as well as physical material.

[19] Olapeju Popoola "Development of a Methodology for the Rapid Implementation of a Sustainable Lean Manufacturing System", (Masters Thesis, Massachusetts Institute of Technology, 2000).
[20] Katzen, James. "Concurrently Designing a Physical Production System and an Information System in a Manufacturing Setting", (Masters Thesis, Massachusetts Institute of Technology, 2003).

2.5 Key Aspects of Transforming to Lean Manufacturing Across Industries

By researching lean transformation approaches in various industries it is possible to identify some aspects that are common approaches among all, which can be considered key. In the examples outlined above there are some themes that seem to dominate; in particular, the importance of targeting lean transformation on the enterprise level, understanding the cultural change necessary for success, and the importance of designing products and processes that facilitate the ability to change and continuously improve on a daily basis.

2.6 Lean Manufacturing Summary

It is clear by comparison of academics, literature, and company examples that there are many different approaches to implementing lean operating systems. However different, all share similarities with the Toyota Production System in the tools and theories. In terms of approach to lean transformation implementation, it is clear that most companies tend to use a phased approach. This typically revolves around understanding and defining how the company delivers value by looking at the value-stream from the enterprise level. Significant effort is then focused on fixing current operations to deliver specific value, promoting process flow and balancing production processes. This step involves all stakeholders and usually requires a culture change which can be a major barrier to taking the next step. The final step is the continuous improvement of production activities, constantly identifying and eliminating waste in the system.

In addition to this phased transition plan, much benefit is derived by applying tools early on in the design phase. The ability to identify and minimize waste in the design process, creating standard work, synchronizing production across the value stream, and involving suppliers and customers in decisions is essential driving successful lean transformations across various industries.

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Chapter 3: Lean Manufacturing at Mitchell Engine Company

3.1 History of Lean Manufacturing at Mitchell Engine Company[21]

During the 1980s, the Mitchell Engine Company began efforts to "lean out" its manufacturing operations. In 1985 Mitchell Engine Company introduced Total Quality Management in the organization. Later on, in 1989, they introduced the IPD program, focused on using cross-functional teams to ensure that engineering, procurement, and manufacturing organizations were involved in design decisions. The result of these initiatives was standardization of many of its materials and manufacturing processes.

In the midst of an industry downturn in 1991, Mitchell Engine Company once again found itself in difficult times. Having witnessed a successful lean transformation effort led by the Japanese consulting firm Shingijutsu at a neighboring organization, senior management at Mitchell Engine Company realized these lean principles would improve their own operations. Throughout the 1990's with the help of Shingijutsu, the company benefited from a number of lean improvements. They began efforts in the Final Assembly Plant, but quickly understood that final assembly could benefit greatly by improving plants that fed that facility. As they continued their journey, they realized many of the improvements depended on related operations or facilities and could not be sustained without the related facilities being improved; however only a finite number of projects could be carried out.[22] As the lean efforts were spread companywide it became increasingly difficult to sustain some of the improvements.

In 1995, Mitchell Engine Company introduced the LEAN operating system building on the momentum gained from surviving increased industry pressure in the early 1990's. While the company continued efforts to implement the LEAN operating system throughout all of its business units some employees within the organization were naturally hesitant to accept change.

At Mitchell Engine Company the majority of the shop floor workers have been with the company between twenty five and thirty years and were somewhat set in their ways. When approached to participate in LEAN projects, the typical reply is: "I already

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[21] Section adopted and modified from Thomas Neal's 2006 LFM Thesis: "Using Optimization and Lean Principles to Design Work Cells and make Capital Purchase Decisions for Hole Drilling Operations in Turbine Airfoil Manufacturing" (Masters Thesis, Massachusetts Institute of Technology 2006). 20-25

[22] James P. Womack and Daniel T. Jones. Lean Thinking, (New York: Free Press, 2003), 167-174

know how to build engines efficiently." These attitudes make it difficult for shop floor managers to promote LEAN activities. The union does not fully support continuous improvement initiatives tied to the LEAN operating system. Shop floor workers have the option to volunteer to become "LEAN Captains," which are "experts" on the shop floor. These LEAN Captains can have a strong impact on how lean is embraced by the workforce, and it would be desirable to have your best mechanics fill these roles, mentoring shop floor workers and managers on the LEAN tools. However it is common for restricted workers in the factory to volunteer; they are typically found collecting LEAN metrics data, taping floors, and participating in Kaizen events. These LEAN Captains do not always have the positive impact on the workforce that the position was intended to have.

The culture at Mitchell Engine Company reflects its history of improvement initiatives, which have been of varied success. The underlying attitude of some employees in the company, therefore, is one of passive resistance and shows low enthusiasm for lean initiatives and resists change. In 2006, the President of Mitchell Engine Company set his number one priority as implementing the LEAN operating system across all business units and functions in the company by May 2008. This renewed focus on LEAN set a clear vision of what is expected, the challenge lies in creating the momentum to successfully "complete" this on-going lean transformation.

3.2 The LEAN Operating System

The approach to lean manufacturing at Mitchell Engine Company is embodied in the LEAN operating system. Before the tools of the LEAN operating system are outlined, it is necessary to state that the tools are used throughout all of their business units. It is not only a "manufacturing" or "operations" initiative, all departments within the organization use the LEAN operating system to streamline and improve the business. In order for this to be possible, Mitchell Engine Company uses Goal Charts to guide management and employees toward specific, measurable goals. Goal Charts exist at various levels in the organization, for example the Final Assembly Plant has a Goal Chart, and Mitchell Engine Company as a whole organization has a Goal Chart. Goal Charts are also established for the near term (1-year) and longer term (5-year) vision.

When looking at a Goal Chart, it is clear they are customer focused. On every Goal Chart, there are four key areas that are addressed:

1) Customer Focus
2) Employee Fulfillment
3) Quality Processes and Products
4) Financial Performance

Goal Chart goals are linked to dandelion charts, known as Performance Sheets at Mitchell Engine Company. These Performance Sheets exist at both the site and cell level, for example, Commercial Production as a "site" has a Performance Sheet, with "Production Assembly – JP-3525" as a "cell" with its own Performance Sheet. These Performance Sheets link Goal Chart goals to yearly metrics which are defined and monitored on monthly intervals. Metrics determining success are defined in the following categories: Customer, Employee Fulfillment, Environmental Health & Safety, Quality, Delivery, and Financial. LEAN tools are used to achieve the Performance Sheet objectives. Levels of success are broken down into four categories, as follows:

- LEAN Qualifying: Metrics being defined, data being collected, and missing any Performance Sheet goal by >10%
- LEAN Red: All LEAN Green metrics established, missing any Performance Sheet goal by <10%
- LEAN Yellow: Meeting or exceeding LEAN Green metrics continuously for 6 months.
- LEAN Green: Sustaining LEAN Green metrics continuously for 12-months.

The ultimate goal of this system is to have all of Mitchell Engine Company's "cells" and "sites" achieving LEAN Green by May of 2008. The tools necessary to achieve these goals will be discussed in the following section. Of course, the journey does not end in 2008, as the metrics as defined in the Performance Sheets will continue to be re-evaluated, requiring that business units continuously improve their business year-over-year.

3.2.1 LEAN Tools

There are 12 individual tools which make up the LEAN operating system. Each of the tools and their purpose are outlined below.

Elements of LEAN

1. 6S & Visual Factory: defined as "A state where anyone can walk into a workplace and understand the current situation without asking anyone else." Successful utilization of this tool enables an outsider unfamiliar with the operations to answer the question, "Are we on schedule?" and can determine if there are any organization and process abnormalities. The elements of 6S are:

- Sort → only keep necessary items in the area
- Straighten → organize the necessary items
- Shine → thoroughly maintain cleanliness of the workplace
- Standardize → establish repeatable procedures
- Safety → create an accident free workplace
- Sustain → continuously improve upon above items

*2. **Total Productive Maintenance (TPM):*** a tool that ensures near 100% equipment availability through active operator involvement in equipment walk-arounds, analysis, and scheduled preventative maintenance.

*2. **Quality Clinic Process Charts (QCPC):*** a tool to identify quality control to help identify quality issues. Problems are recorded on specific sequences and identified for corrective action.

*4. **Relentless Root Cause Analysis (RRCA):*** a tool used to identify the true source of problems to prevent reoccurrence. Typically, the "5 Whys" are used as a means of identifying the root causes of problems.

*5. **Mistake Proofing:*** a tool used to ascertain defect-free work by ensuring that a task is always performed properly.

*6. **Market Feedback Analysis (MFA):*** collection and analysis of customer feedback data to track product performance allowing for future quality and reliability improvements and ensuring the customers' needs are being met.

*7. **Process Certification:*** a tool used to assure that processes are standardized and repeatable, capable of producing a reliable product/service with minimal variation.

8. Standard Work: promote repeatable processes which lead to efficiency and effectiveness.

9. Setup Reduction: reduce labor input and minimize time to change-over and set up production tooling during assembly.

10. Passport System: a tool the enables new designs to be reviewed and approved in a systematic way, similar to a phased gate approach.

11. Production Preparation Process (3P): 3P seeks to meet customer requirements by starting with a clean product development slate to rapidly create and test potential product and process designs that require the least time, material, and capital resources.[23]

12. Value Stream Mapping (VSM): Generally defined as the entire material and information flow of a product or service from a producer to a consumer, it is method of visually mapping a product's production path from "door to door". It includes all the actions that are required to bring a product through the entire process. It shows the linkage between the information flow and the material flow.[24]

3.3 Comparison of LEAN tools to Toyota's Lean Principles

In studying the tools, it is clear that the LEAN operating system was designed to blend the principles of lean manufacturing as they are found in the Toyota Production System along with Dr. Edward Demings summary of the Total Quality Management philosophy. Of the LEAN tools, five of them stem from the origins of lean manufacturing as they are found in the general philosophy of the Toyota Production System. These tools are:

- 6S & Visual Factory
- Total Productive Maintenance (TPM)
- Standard Work
- Setup Reduction
- Value Stream Mapping

Demings' TQM teachings compromise 6 of the remaining tools found in the LEAN operating system, these tools are outlined below:

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[23] http://www.epa.gov/lean/thinking/threep.htm, May 2007

[24] http://en.wikipedia.org/wiki/Value_Stream_Mapping , May 2007

- Quality Clinic Process Charts (QCPC)
- Relentless Root Cause Analysis (RRCA)
- Market Feedback Analysis (MFA)
- Process Certification
- Passport System
- Production Preparation Process (3P)

The final tool, Mistake Proofing, blends the aspects of both philosophies, and thus is difficult to assign to either category.

Overall at Mitchell Engine Company it is believed there are significant advantages to combining both lean and TQM into one operating system. A former Final Assembly Plant Manager and current VP at Mitchell Engine Company wrote in his MIT Sloan School of Management Thesis in 2004:

> "Combining both lean and TQM tools into one operating system in a corporation that has such diverse product offerings as Mitchell Engine Company, is not only unique, but demonstrates high effectivity of the LEAN operating system. This ability also demonstrates the opportunity for LEAN to aid the supply chain and value stream partners as well as most other companies. It is of great value to practitioners of LEAN to be able to have one operating system, verses multiple ones, in order to drive improvement across their businesses. Most companies today require both cost reduction and productivity types of internal operating improvements as well as improved customer satisfaction and top line growth. LEAN has the ability to deliver both in one system."

Chapter 4: Lean Transformation Case Study

4.1 Mitchell Engine Company Lean Transformation Case Study

Having introduced the reader to the principles of lean manufacturing, identified some industry approaches and discussed some of the research on the topic, I would like to now devote attention to my experience at Mitchell Engine Company. This chapter will provide background on the Final Assembly Plant, production operations, and jet engine assembly. Particular attention will be paid to the JP-3525 commercial aircraft engine, focusing on lean implementation efforts in the fan case assembly cell serving as a case study outlining my internship experience.

4.2 Mitchell Engine Company Final Assembly Plant

The Mitchell Engine Company Final Assembly Plant is an 1100 acre site employing approximately 3000 workers across various departments.[25] The Final Assembly Plant mechanics and assembly technicians are bargaining unit members.

The Final Assembly Plant serves as the facility in which final assembly and test for commercial and military aircraft engines. On the assembly side of the business, it serves two major functions for Mitchell Engine Company, production and validation. Production includes engines sold to commercial and military customers which are assembled, tested, and shipped to the airframe manufacturer for installation. Validation has the function of "validating" new designs as well as design changes. Engines that are not yet in the production phase are assembled at the Final Assembly Plant as part of the validation group. Having gone through many hours of testing but still being manufactured at very low volumes, validation serves both to improve assembly operations, but also to test new & "tear-down" engines to analyze the findings as part of the engine approval protocol. It provides both the customers and the designers with vital performance and maintenance information.

In addition to new engine design, validation also works with older model engines to test design changes and improvement initiatives focused on increasing time on-wing or decreasing fuel burn, for example. This involves bringing older engines in house, tearing them down, rebuilding them in their "improved" state, and verifying the results through

[25] Center for Land Use Interpretation: http://ludb.clui.org/ex/i/CT3137/

testing. In both cases, the validation process involves many labor hours in both the assembly/disassembly process as well as preparing the engines for test, which often involves the installation of thousands of sensors. Since the validation group deals with very low volumes or special programs, many of the operations are not repeatable or come through on a "one-time" basis.

4.3 Final Assembly Plant Production Operations

As the location of final assembly and test for both commercial and military engines, the Final Assembly Plant is where Mitchell Engine Company is closest to the customer and is often referred to as a showcase. Visitors including US military, airframe manufactures, and commercial airlines are often spotted touring the facility. As a result, production floor appearance is a high priority. Engines are arranged in flow lines split between military and commercial models. This arrangement allows the customers to walk the aisles and see the "value stream" from the end to the beginning of final assembly for each model. Many visitors are impressed with production area, as is the intent, with recent upgrades in lighting and the move away from black floors have improved its appearance, enhancing both the customer & employee experience. Many of the improvements are directly tied to the lean transformation that has taken place since the implementation of the LEAN operating system.

4.4 Introduction to Gas Turbine Fundamentals and Assembly

4.4.1 Basics of Gas Turbine Operation

A gas turbine engine is made up of five distinct sections; also know as modules, when assembled. Figure 3 below shows a cutaway view of a typical jet engine. Engines manufactured today closely resemble the figure shown. The five main sections that make up a jet engine are the low pressure compressor, high pressure compressor, diffuser (including the combustion chamber), high pressure turbine, and the low pressure turbine.

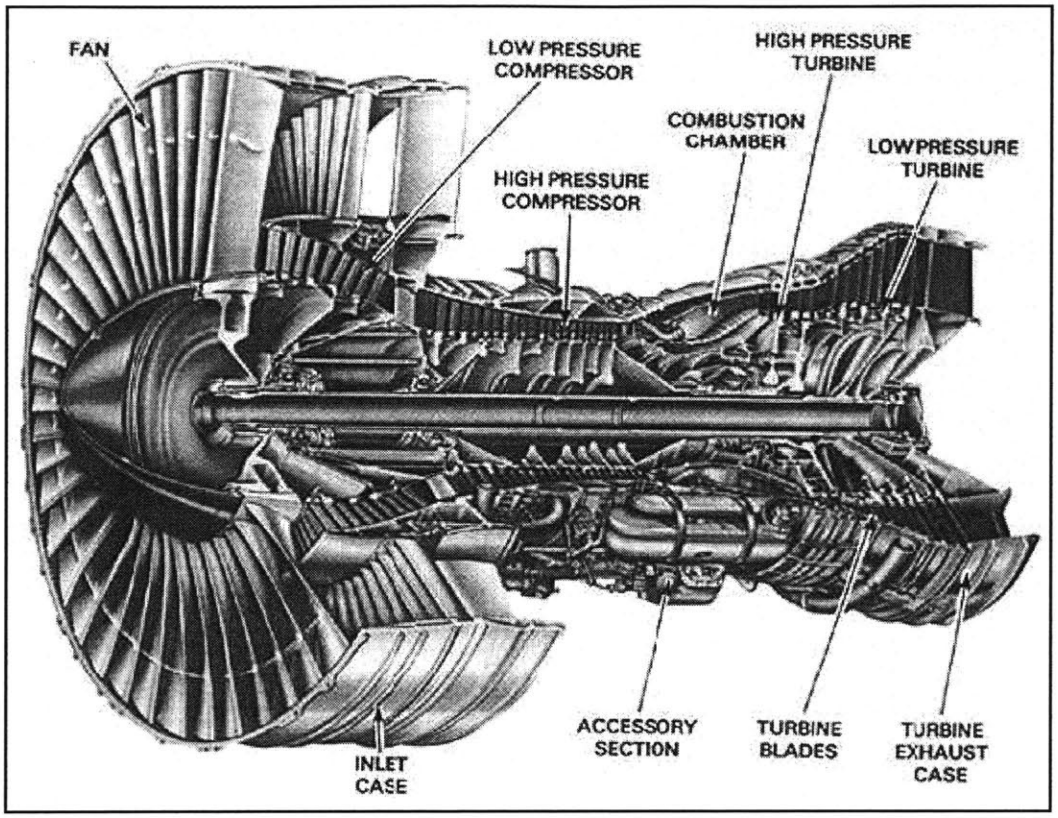

Figure 2 – Typical Jet Engine[26]

One of the basic fundamentals of aircraft engine operation is they are designed with two shafts, known as a shaft within a shaft configuration. The high pressure compressor & high pressure turbine share a common shaft and spin at the same RPM, while the low pressure compressor and low pressure turbine share a shaft and rotate at a slower RPM.

A brief description of each of the five basic sections that make up gas turbine engine is given below, and should provide adequate information to understand future sections of this thesis.

- **Low Pressure Compressor (LPC) –** the low pressure compressor is housed in the fan case or inlet case, and it serves to increase the pressure and velocity of inlet air. The fan itself is considered part of the low pressure compressor. On smaller engines, the fan case houses many auxiliaries including the gearbox, making them significantly more difficult to assemble.

[26] Source: http://home.swipnet.se/~w-65189/transport_aircraft/b747/jt9d_cutaway2.jpg

- **High Pressure Compressor (HPC) –** the high pressure compressor is attached to low pressure compressor. As air travels through the high pressure compressor, it increases greatly in pressure, temperature, and velocity. Air exits the HPC it enters the diffuser and combustion chamber.
- **Diffuser & Combustion Chamber –** is attached to the high pressure compressor. Air at high temperature and pressure enter the diffuser, fuel is added, and it burns in the combustion chamber, adding heat energy to expand the air and accelerate the mass flow into the high pressure turbine.
- **High Pressure Turbine (HPT) –** as the expanding gases leave the combustor it enters the high-pressure turbine which begins to extract kinetic energy and converts it into shaft horsepower to drive the high pressure compressor.
- **Low Pressure Turbine (LPT) –** before the hot gases leave the core as exhaust, the low pressure turbine extracts most of the remaining energy, converting it to shaft horsepower to turn the low pressure compressor and fan.

The next section will give a basic introduction to a typical jet engine assembly sequence as it would occur in the Final Assembly Plant.

4.4.2 Gas Turbine Assembly

When considering gas turbine assembly, it is important to note that all five sections that make up the engine are connected to each other. The assembly descriptions below apply specifically to commercial engine assembly and the same assembly process may not necessarily apply to military engines.

Commercial jet engine assembly typically begins with the fan case module and includes installation of the low pressure compressor in place within the fan case. This is done with the fan case in its "vertical" configuration so as to use the forces of gravity to assist assembly. The low pressure compressor is assembled into the fan case from above, and it is "stacked" onto the fan case housing. Figure 3 shows this configuration.

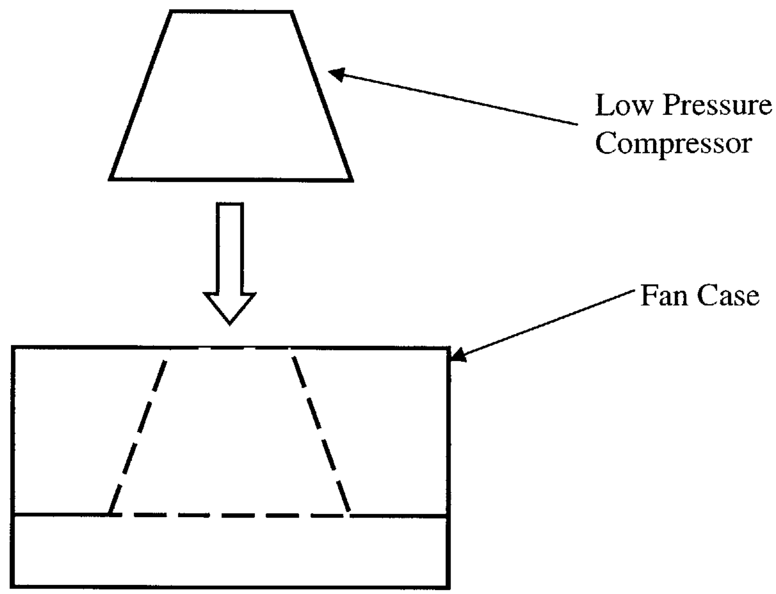

Figure 3 – Installation of Low Compressor into Fan Case

After mating, the fan case is typically outfitted with auxiliary equipment and associated piping and wiring depending on the engine model. In many engine designs the fan case is the most complex complete assembly. Since it has the longest cycle time and the rest of the modules are stacked vertically onto the low compressor housed within the fan case, this assembly begins the production sequence.

While the fan case is being assembled, the diffuser, high pressure compressor and high pressure turbine are concurrently being assembled with their individual components either in-house or by a supplier. Once each of these modules is complete they can be stacked. The diffuser is mated with the high pressure compressor, and the high pressure turbine then mates with the diffuser. This assembly is shown in Figure 4.

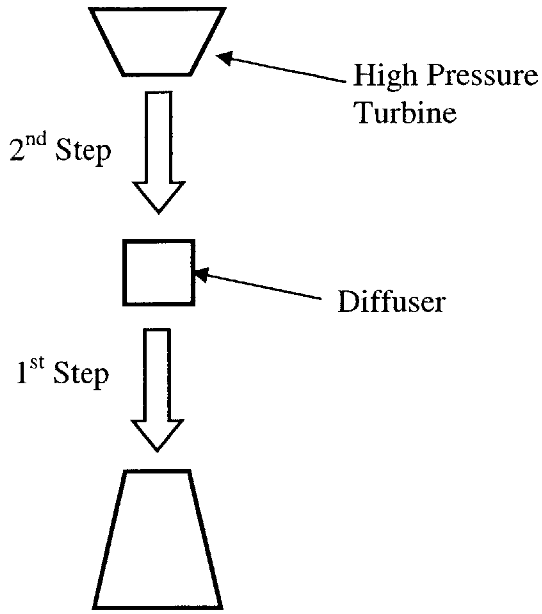

Figure 4 – Core Assembly

Once the core is successfully assembled, it can be mated with the fan case assembly. After the core is mated to the fan case the new assembly is then tipped horizontally. The low pressure turbine is assembled with the engine in its horizontal position. The final step in the assembly process is the installation of the fan. Figures 5, 6 and 7 illustrate these final steps.

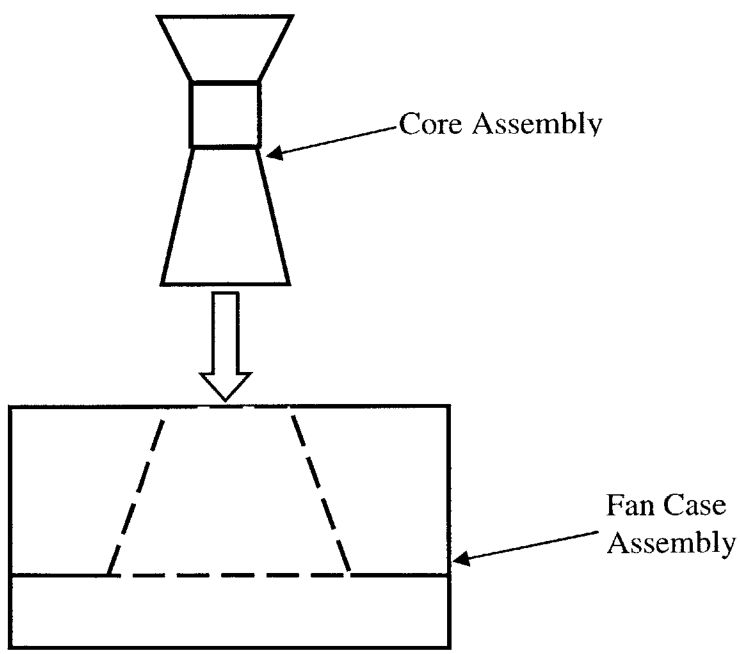

Figure 5 – Mating of Core to Low Compressor

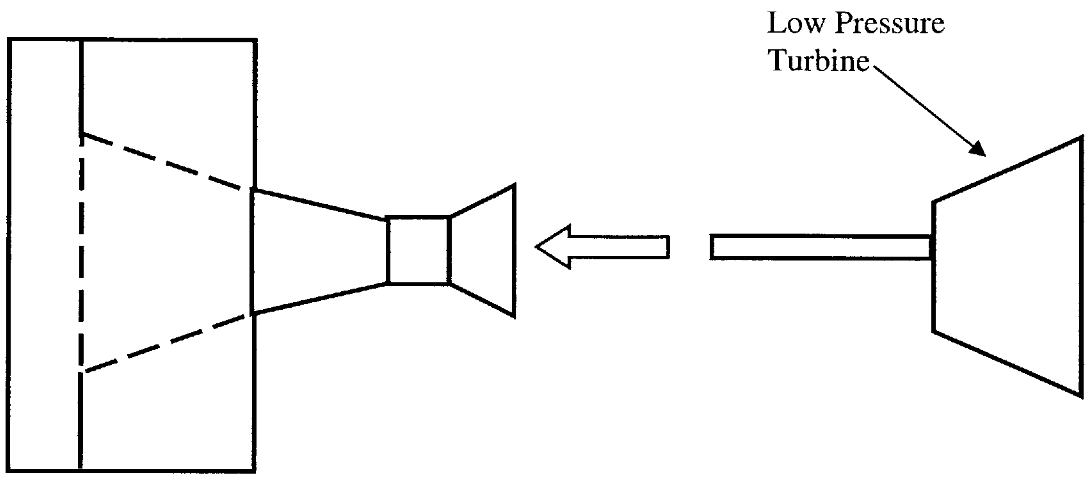

Figure 6 – Mating of Low Pressure Turbine

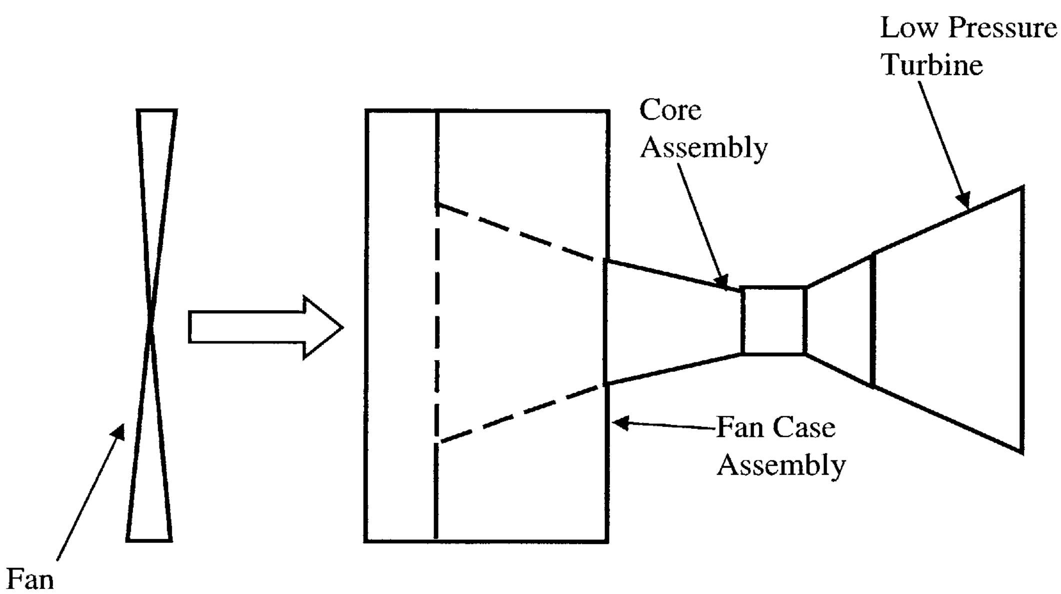

Figure 7 – Installation of Fan

4.5 Final Assembly Plant Operations Vision

With a basic understanding of the assembly process it is apparent that engine assembly is complicated. Each of the individual sections need be assembled with their own piece parts, with additional piece parts to be added within each of the steps as sections are mated. Coordination and synchronization of the entire global supply chain is essential to meet customer needs and deliver engines on time.

The goal of the lean transformation in the Final Assembly Plant is to increase value stream steam performance and velocity, while reducing work-in-process along the engine assembly flow lines. Engine parts, assemblies, kits, and modules come from hundreds of suppliers, world-wide partners, and Mitchell Engine Company's own internal manufacturing sites to the Final Assembly Plant for final assembly and test. Competitive pressures in the industry and the availability of low cost labor have put increased pressure on the Final Assembly Plant. Value stream performance and productivity improvements are crucial to the future success of commercial engine assembly at Mitchell Engine Company.

In recent years, the Final Assembly Plant has moved away from performing many of the low value add steps of assembling parts in-house and has defined its core competency as engine assembly. Driven by lean manufacturing philosophy, assembly operations continue to transform to increasingly modular builds on moving flow lines. Ultimately, the goal of the lean transformation is to minimize the time it takes to assemble, test, and deliver an engine in order to reduce operating costs, WIP, inventory levels, and allow them to more quickly adapt to changing customer needs.

4.6 Final Assembly Plant Approach to LEAN

Commercial and military final assembly operations are in the process of moving towards LEAN Green. Currently the individual "cells" in the facility are in various stages of the journey, with most currently at the LEAN Red level. Metrics are established, and the LEAN tools are being implemented and utilized to meet the goals set out in the Performance Sheets.

At this point in the implementation process, heavy emphasis is put on a number of specific LEAN tools. Most of the efforts currently focus on 6S/Visual Factory metrics, as well as Standard Work. However, each of the other tools inter-twine into these efforts in varying degrees. Much of the focus on 6S & Visual Factory comes from the belief that the first step to becoming LEAN Green is to make it look LEAN Green. This is of increasing importance in the Final Assembly Plant, as it also enhances the customer experience. Evidence of these efforts can be seen in recent capital improvements including new light-grey flooring, white walls, and installation of improved lighting throughout the entire facility. Additional elements of 6S are also being implemented with sort, straighten, shine, standardize activities occurring daily and scorecards being generated in an effort to sustain these improvements.

The focus on standard work in the Final Assembly Plant has also shown promising results of recent. Much attention is paid to establishing "Pitch" across engine flow lines. "Pitch" attempts to define a "standard increment of work that can be expected to be completed in a single shift, typically 7 hours, delivered on a single material cart." The theory is that if we can "pitch" a certain amount of work to the shop floor employees at the beginning of a shift they should be able to complete that work within a shift. The implementation of pitch across assembly lines should assist in sequencing production operations, promote balanced line loading and flow lines. Pitch will also help identify problems as they arise in production. If a pitch cart falls behind over the course of the shift, or if it is not completed as expected, it is clear a problem has arisen and needs to be addressed. Pitch serves two major functions: it sets a clear work expectation from which mechanic performance can be monitored, and it creates a visual factory arrangement that allows managers greater visibility into production efficiencies or issues.

In the Final Assembly Plant there is belief that focusing on 6S/Visual Factory along with setting a work expectation by defining Standard Work are the areas that present the greatest opportunity. Once implemented, the remaining tools will be more effectively utilized. Based on the current state of operations at the beginning of my internship at Mitchell Engine Company, a case study was developed which shows the applicability of the LEAN tools to the JP-3525 Fan Case assembly area.

4.7 Introduction to the JP-3525 Commercial Aircraft Engine

Operating in the 25,000 thrust class, the JP-3525 is the highest volume engine assembled in the Final Assembly Plant. With a monthly demand of 15-17 engines, the plant has to deliver an engine every 1.3 working days to meet customer demand. The JP-3525 was developed under a consortium, with four major partners involved, each owning part of the production, and sharing profits. Final assembly is split between Mitchell

Engine Company and the European firm who owns the engine design. Each of the four consortium members manufactures different engine modules. Mitchell Engine Company manufactures the high-pressure turbine and diffuser. The fan case and low pressure compressor comes from a Japanese firm, and the high pressure compressor and low pressure turbine come from two different suppliers in Europe.

The consortium arrangement results in a complex supply chain as each member must depend on others to deliver on time to meet customer expectations. A degree of complexity is added, however, since Mitchell Engine Company is a major competitor with the firm that owns the engine design on other engine model lines. While this consortium arrangement has these two companies working together, there is increased complexity in coordinating activities typically found in outsourcing agreements. These relationships have significant impact on determining production schedule, sequencing value stream operations across the critical path, and sharing improvement activities across firms. Each of these activities could be potential barriers to fully realizing the benefits of lean transformation.

Despite some of the increased complexity associated with working with a consortium the engine program has been an extremely successful one in the aviation industry. To date, orders have exceeded $35B with over 2,600 engines delivered. More recently, Mitchell Engine Company has been able to successfully implement pitch and create 6S/Visual factory arrangement on the vertical & horizontal final assembly line. Using the JP-3525 as an example, the Final Assembly Plant is attempting to achieve its first LEAN Green commercial production cell. In order to achieve this goal, a reduction in cycle time and process variability must be achieved in the JP-3525 fan case assembly cell.

4.7.1 JP-3525 Fan Case

Being a JP-3525 fan case assembly operator is arguably the most challenging shop floor job in the Final Assembly Plant. Unlike most operations, the JP-3525 fan case assembly is extremely labor intensive. Because of their size and complexity, the fan case & installed low pressure compressor are delivered to the Final Assembly Plant without any of its auxiliary components, wiring, or piping installed.

The fan case goes through 14 operations, each made up of numerous production sequences before it can be delivered to the vertical assembly line for mating with the high pressure compressor. In these process steps many auxiliary components are installed onto the fan case, including the gearbox, fuel pump, engine control unit, fuel cooler, lube-oil coolers and associated wiring and piping essential to final engine operation. Shop floor mechanics who work on this assembly compare the fan case assembly to preparing lasagna, "You slowly have to build it up, layer by layer; there is no way to get around it." The relatively small size of this engine makes assembly operations all the more difficult, since there is less room to fit components.

In addition to the difficulty of the production process, the JP-3525 fan case assembly cell had gone through some recent transitions resulting in sub-optimal production results. Having been moved from another part of the factory in a past Kaizen event, there was insufficient follow-through in completing the project. Although improvements had been implemented in tooling and the number of fan cases in WIP had been reduced from 8 to 6, the assembly cell itself was not ideal for the production process. The space was cramped, 6S/Visual factory metrics weren't being utilized, and the assembly workers felt their old area was better suited and more productive. The cramped workspace did not promote process flow, and cycle times had high variability. Figure 8 shows the physical layout of the assembly cell at the beginning of the project.

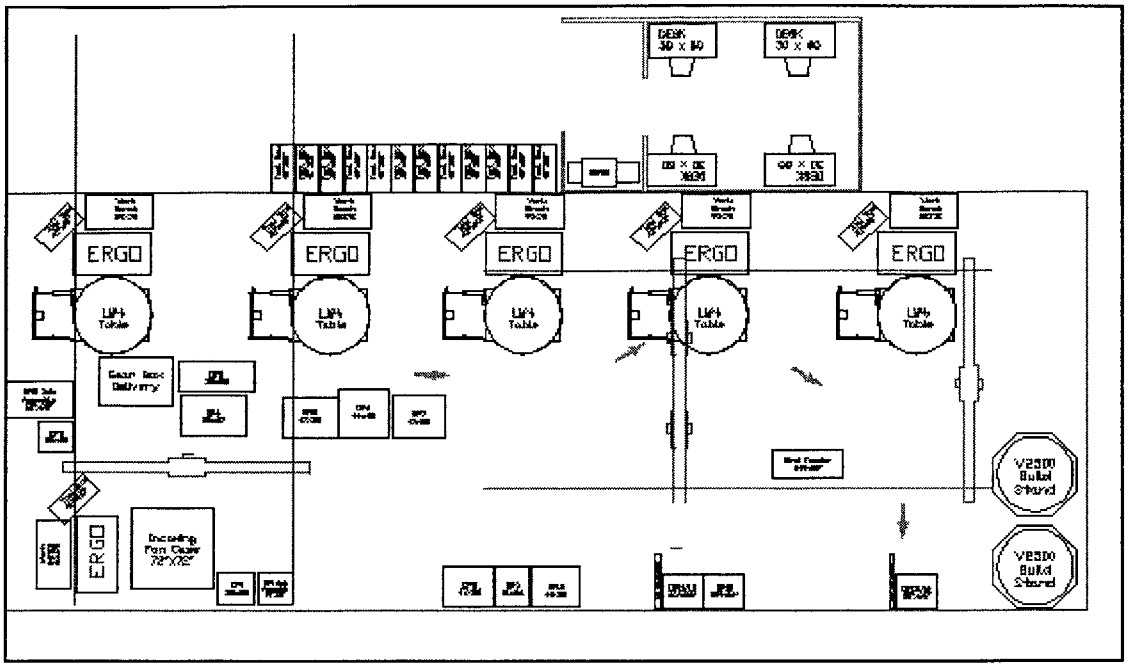

Figure 8 – JP-3525 Fan Case Assembly Cell Layout (June, 2006)

The combination of these factors resulted in sub-optimal product cycle time performance. In June of 2006, the average cycle time of a JP-3525 fan case was 9.7 days with a standard deviation of 2.3, as seen in Figure 9. On an engine with a takt time of 1.3 days, the inconsistent lead time of the fan case subassembly often resulted in production delays on the final assembly line. This increased the overall product cycle time having a negative effect on product delivery since the fan case build sequence must begin before many of the other modules were received in the factory. The belief was that a reduction in fan case cycle time and its variability would have a significant impact on the other production processes downstream in the JP-3525 value stream.

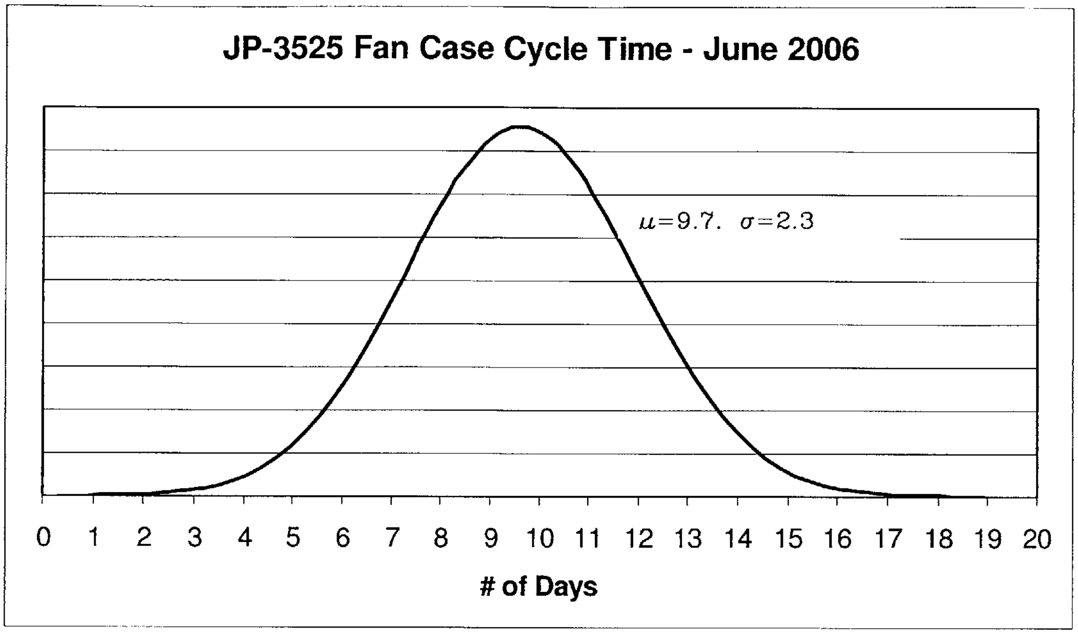

Figure 9 – JP-3525 Fan Case Lead Time (June, 2006)

4.7.2 JP-3525 Fan Case Project Focus & Goals

Given the current state of the fan case assembly cell it was determined that the project would focus on the following LEAN initiatives:

- Redesign the fan case assembly cell incorporating 6S/Visual factory arrangement including production load balance across workstations.
- Reduce cycle time variability and promote process flow in the assembly cell by determining and implementing employee work standards, and driving "Pitch" within the cell.

4.7.3 JP-3525 Fan Case Lean Transformation Approach

With significant focus on shop floor improvement, much time was spent working directly with assembly operators. Collecting data from them both through observations and conversations was an essential element to determining how to approach the problem. Initial efforts focused on building personal relationships with the assembly technicians so they didn't perceive this project as a threat. Although this took longer than expected the up-front relationship building was a key element to project success.

Once the mechanics understood the goals of the project, most assembly operators were supportive of the work and appreciative of the attention and help. Many understood the objectives and were always willing to discuss challenges and provide their input on items that directly affected them, making sure their opinions were being heard. The fact that the footprint of their assembly cell was going to be increasing was a huge boost in worker engagement, one of the early quick wins that helped build the credibility of the project among the workforce.

In order to better understand the challenges, much time was spent getting to know the processes, and determining standard times for each of the 14 operations. While physical process time data would have been useful for determining "pitch" and the design of the assembly cell with balanced workstation loading, it was unavailable. Instead, process times were determined through observation and discussion with 1^{st} and 2^{nd} shift employees whose involvement created a sense of ownership in the project. Their input and cooperation were essential to effectively redesigning the fan case assembly cell to promote flow, point-of-use tooling, visual factory, and a leveled production load.

While most workers were quite content discussing change, at times it was challenging to get them to embrace and help implement some of the improvements. During the implementation phase of the project, LEAN Captains were a useful resource on 1^{st} shift, while many of the assembly technicians on 2^{nd} shift were fully involved in implementing the improvements. This momentum continued to build throughout the project as their level of engagement increased when visible improvements became evident. Towards the end of the project some workers would openly voice their opinion as to what they would like to improve next, a sure sign they were engaged and excited about the project and future opportunities.

4.8 JP-3525 Lean Transformation Accomplishments

Over the course of the internship, improvements were realized in both assembly cell layout as well as the initial steps towards creating a "pulse" flow of fan cases throughout the cell.

4.8.1 Assembly Cell Redesign

Both the Plant Manager and Product Line Director supported the improvement activities, and dedicated resources to expanding the assembly cell. While this project took about four months to complete, the timing was critical to allow the collaboration of the flow line manager, product line manager, cell leaders, and assembly workers to coordinate efforts, create a plan, and be prepared to deliver on promised items once the expansion project was complete. Figure 10 depicts the new fan case assembly area.

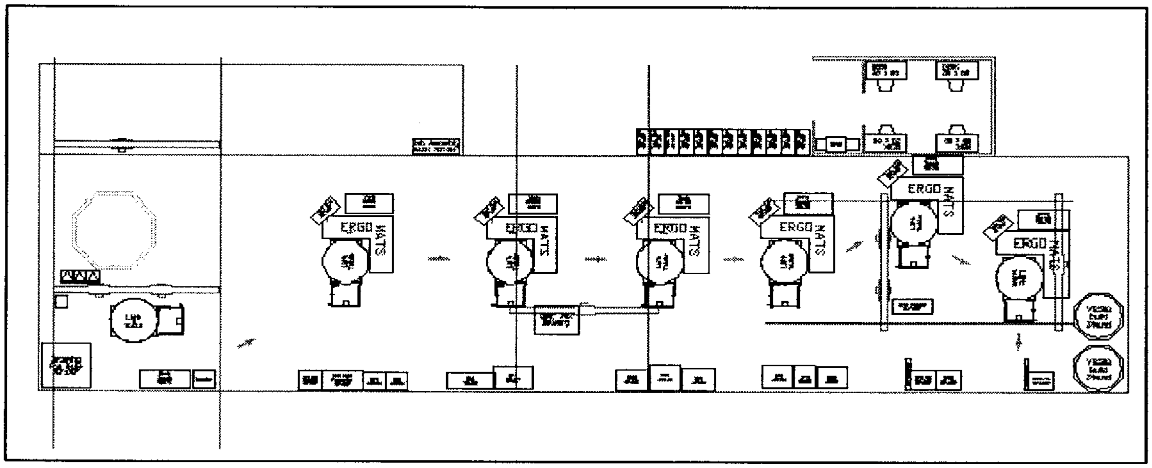

Figure 10 – Redesigned JP-3525 Fan Case Assembly Cell Layout

In addition to expansion of the assembly cell other outstanding improvement items were incorporated into the project. From an ergonomic standpoint, new adjustable workstations outfitted with 37" LCD TV's were installed, allowing the workers to read work instructions while working on the fan case from a distance. Tilted shelves were fitted to help eliminate ergonomic injury caused by reaching for parts and supplemental instruction manuals. New ergonomic mats were purchased and installed to minimize the ill-effects of standing on hard surfaces for an entire 8-hour shift. Additionally within the cell much focus was spent on 6S; determining permanent locations for material delivery as well as storage of tooling and items used to assist during production. The new organization and arrangement of the fan case assembly area eliminated much of the ergonomic risk inherent in a cramped space, promoting both visual factory metrics as well as flow.

4.8.2 Balanced Line and Fan Case Pulse Flow

In the course of redesigning the assembly cell much attention was focused on balancing workstation load and promoting a "pulse" flow. As a first attempt to determining "pitch" in the area, working closely with the mechanics and interpreting the minimal data that was available, approximate sequence times were determined. Based on these times, the assembly cell was divided into 6 workstations, each arranged so that approximately three shifts worth of work would be completed before the fan case would "flow" to the next station. This flow was determined by the takt time, generated by customer demand, which equaled 1.3 days. In a two shift operation, this is slightly less than 3 shifts, however, both overtime and the alternative work week crew which typically worked on weekends was not included in this takt time calculation. While not the current state of operations in the JP-3525 fan case assembly area, it was management vision to minimize overtime and weekend work. In this new arrangement it was expected to take 18 shifts to complete a fan case, resulting in an average cycle time of 9 days. Figure 11 shows the balanced workstation load in this assembly cell arrangement.

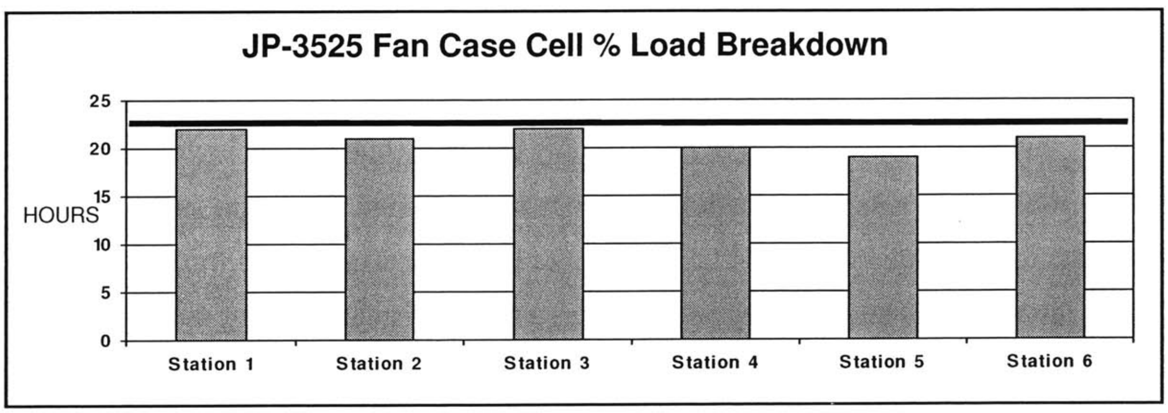

Figure 11 – JP-3525 Fan Case Workstation Load Balance

Balancing workstation load is a first attempt towards determining and implementing pitch. These times were established by working directly with assembly floor operators, and establishing approximations based on their input. It also breaks down work according to the current operation breakdown of 14 separate operations. These 14 operations are tied to bill-of-materials, which through the MRP system get released to the line. Without detailed data on the process steps it was not possible to directly determine pitch which would have resulted in changes in BOM structures. This would have created significant work for the supply chain organization, including the modification of material carts. It seemed that a first cut attempt would help management better understand the process, and put systems in place to capture detailed sequence level time data. Once this was done, pitch could be defined more accurately. At the time of this project, balancing workstation load based on the operations level was a logical first attempt at reducing process variability, setting the baseline for refinement within the cell.

4.8.3 JP-3525 Fan Case Lean Transformation Performance Results

In addition to the physical improvements and creation of a visual factory arrangement, the fan case area has realized improvements in process efficiency. Improvements were noticeable during observation; fan cases began to flow through the assembly cell from start to finish, and the build-up of both empty fan cases waiting production as well as complete fan cases waiting to be mated with the high-pressure compressors occurred less frequently. The assembly cell redesign with load leveling of workstations has resulted in cycle time and variability improvements. Figure 12 shows the improved fan case lead time and reduced process variability as of December, 2006 compared to the data taken in June, 2006.

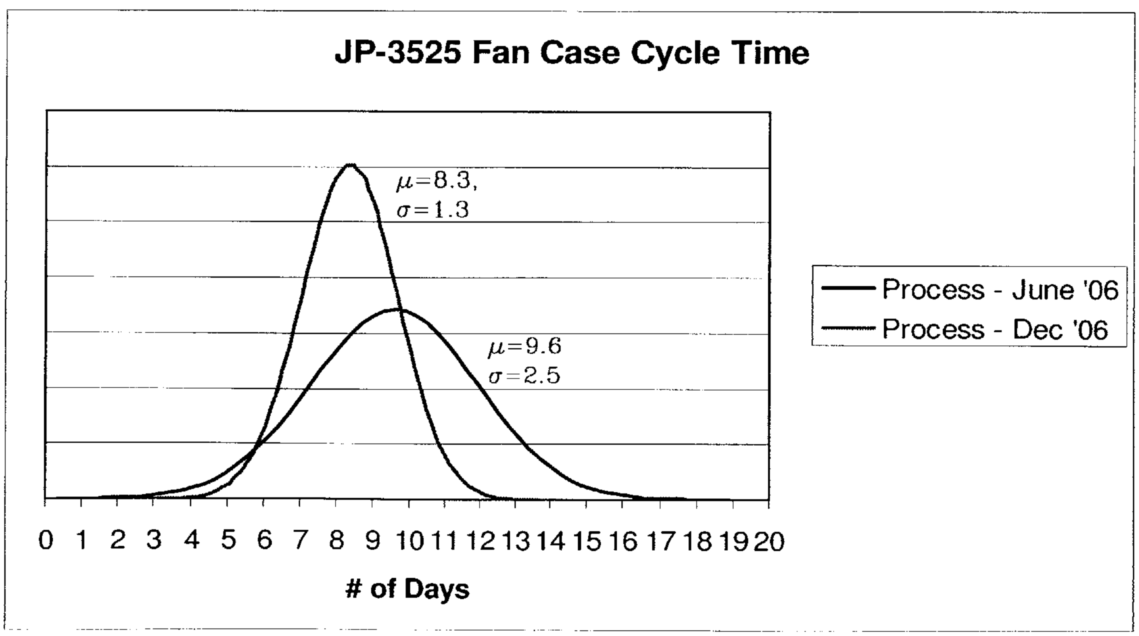

Figure 12 – JP-3525 Fan Case Cycle Time Data

This 15% cycle time improvement results in shortening the overall time along the critical path of JP-3525 engine assembly, allowing Mitchell Engine Company to realize a reduction in overall engine cycle time. Moreover, the reduction in standard deviation from 2.5 days to 1.3 days shows an improvement in cycle time variability. While 1.3 days is still high when compared to the takt time, the performance is trending in the right direction.

4.9 JP-3525 Lean Transformation Challenges

Overall the lean implementation had successful results, however there were a number of challenges encountered along the way preventing further improvements being realized. While lack of good available data was mentioned as a hindrance to successfully determining pitch, there were a number of non-tangible factors that were difficult to work around.

4.9.1 Involvement of Shop-Floor Labor

While shop-floor mechanics were a vital resource throughout this project, it took them some time to understand and become involved in the project. There was some concern that participating in activities to improve productivity would result in a decrease of overtime pay, reducing their overall pay. Over time they had become accustomed to the increased wage overtime allowed them to earn. This sentiment made it clear that there was a need to put in place an incentive system which gives the shop-floor employees a share of the profits generated by these improvement activities. Not being able to personally benefit from improvement activities made it difficult for management to create the momentum necessary to fully realize the benefits of the LEAN operating system.

Another dynamic that existed was the varied performance level of shop floor employees in the assembly cell. Some mechanics would complete 5 sequences in a day while others would do 25. This situation was challenging when trying to determine the standard work expectation. When it came to setting pitch increments, the question was "whose 7-hours of work will be the baseline"? Knowing the answer would need to be somewhere in between, the high performing mechanics felt that implementing pitch would ultimately reduce their overtime pay, one of the few incentives they enjoyed.

4.9.2 Involvement of Front Line Supervisors

In the limited role of an intern the boundaries of what I could and could not do were clearly defined. At times being an intern was clearly advantageous, as I could take calculated risks with little downside. At other times the lack of authority in my position made promoting change very difficult. When process improvements were identified which required workers to change the way they did things, I was limited to making suggestions. While many of the improvement efforts were appreciated some shop floor employees would often ask why their cell leader wasn't involved more as their direct supervisor. To their defense in the fan case assembly cell both the 1st and 2nd shift supervisors were new to the position, and were coming up to speed quickly as they moved down the learning curve. It seems that there is an opportunity here to begin repairing these relationships subtly, as efforts surrounding the LEAN initiative are high and funds for improvement may allow cell leaders to accomplish significant change quicker than normal given the circumstances.

Success depends on numerous factors, two of which are having the right person in the cell leader position, and ensuring their metrics are aligned with those of the LEAN operating system. In the next chapter the role of front line supervisors will be analyzed in significantly more detail, focused largely on the uniqueness of the position and how it can be better utilized to achieve successful lean transformation in the organization.

4.9.3 Communication

Lack of communication within the organization was evident at times during the project. While working with engineering, attempts were made to determine the status of improvement initiatives inherited by my project resulting in many unanswered phone calls. On the shop floor it became evident that there was a lack of communication between cell leaders and mechanics on 1st and 2nd shifts in the same cell regarding production status. Popular tools that promote communication, such as toolbox meetings were held inconsistently. Throughout a shift cell leaders often did not engage the workforce and mechanics rarely approached their supervisors.

There was also a lack of communication surrounding LEAN operating system efforts in the plant as well. During the first all hands meeting attended, LEAN was not mentioned at all and in the second it was briefly discussed. There was no open discussion between management and the union that discussed the increasing business challenges and the general need to improve operations. Other than all-hands meetings mechanics were not given the opportunity to openly voice their concerns.

Increasing communication throughout the organization is an area of great opportunity and is necessary to improve employee/management relationships. Additionally, communication regarding the LEAN operating system focusing on the benefits, needs, and challenges faced by Mitchell Engine Company needs to take place in order to achieve the results the system is capable of delivering. Figure 13 shows both the management and labor perception of the LEAN operating system.

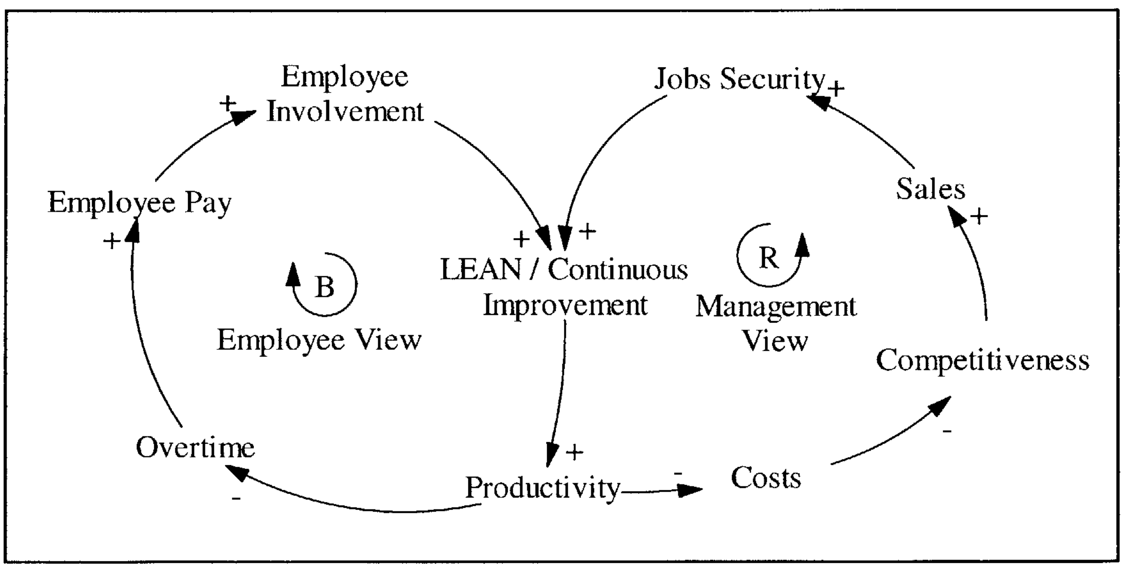

Figure 13: Conflicting views on LEAN

In the loop labeled "Employee View" LEAN is seen as a means of increasing productivity on the shop floor. In their mind, this increased productivity leads to a decrease in overtime, which ultimately decreases their take home pay. A decrease in take-home pay decreases employee involvement, and LEAN/Continuous Improvement cannot be fully realized without shop-floor employee involvement. This balancing loop needs to be broken in order to fully realize the benefits of the LEAN operating system.

In the "Management View" loop, the increased productivity from the LEAN operating system allows the Final Assembly Plant to decrease production costs. These decreased costs improve the market competitiveness of Mitchell Engine Company products. Improved competitiveness thus increases overall sales resulting in the need to keep production jobs, promoting job security. This increased job security reinforces the benefits of LEAN/Continuous Improvement among the workforce, creating a reinforcing loop to build and sustain momentum for the program.

4.9.4 Product and Process Design Control

As mentioned earlier in this chapter, the JP-3525 design is owned by another firm. This creates a difficult dynamic for the engineering focused culture at Mitchell Engine Company, as they do not have ultimate control over product and process design changes. At times this lack of control limits what Mitchell Engine Company can change when they identify process or design improvements during Kaizen events. While there is an agreement in place to work with the engine designer all decisions go through careful review and cost/benefit analysis. This process along with FAA involvement often results in long lead times for design related improvement projects.

On future engine designs, the addition of the 3P tool in the LEAN operating system should help reduce the need to make process improvements along the way, but is not likely to eliminate it entirely. Clearly it is difficult to make changes on an engine design that has been in production since the mid 1980's. Such models did not have the benefit or attention paid as much to design for manufacturing or standardized parts. The real benefit of 3P and design for manufacturability will be recognized on the next generation of aircraft engines Mitchell Engine Company is currently developing. Moving forward, they should look at ways all consortium members can use the LEAN operating system tools to maximize production efficiency.

4.10 Chapter Summary

This chapter has introduced the reader to a case study on a particular implementation project, and some of the challenges associated with it. While positive results were realized their impact was limited by a number of challenges. In the next chapter I will discuss one of these challenges in detail; looking at the organization through the political, cultural, and strategic lenses and specifically discussing the role of the cell leader in programs such as LEAN. The dynamics of the position will be outlined to show how the traditional role of the front line supervisor needs to be redefined to ensure successful change initiative.

Chapter 5: Organizational Analysis

5.1 Organizational Analysis as viewed through Three Lenses

A common tool used to analyze companies from an organization perspective is through the Three Lenses: political, cultural, and strategic. The following section will discuss my view of the Final Assembly Plant through these three lenses and will touch on some aspects which have already been discussed in the previous chapters of this thesis. Each lens is broken down in Table 2:

	Strategic Lens	Political Lens	Cultural Lens
Key concepts	Formal structure ("the boxes," business processes), systems (info systems, human resource management, etc.)	Power and influence, social networks, interests, dominant coalition	Identity, traditions, shared mental maps, cultural artifacts, values and assumptions
Key processes	Grouping, linking, aligning, external fit	Conflict, negotiation, forming (dissolving) relationships	Meaning and interpretation, legitimizing, rhetoric, setting norms/rules of conduct
View of Environment	Opportunities and threats	Stakeholders	Social and cultural network, institution
Role of leader	Organizational architect, strategist	Building coalitions, identifying and leveraging interests, negotiating and resolving conflicts	Articulating vision, build and manage culture, symbol of culture
Stimuli for change	Lack of internal integration, lack of fit between organization and environment	Shifts in dominant coalition, in power of stakeholders	Challenges to basic assumptions, contested interpretations
Barriers to change	Inadequate analysis, inadequate information	Entrenched interests	Dominant culture

Table 2: Characteristics of the Three Lenses[27]

5.1.1 Organization as viewed through the Strategic Lens

The LEAN Manager is a direct report to the GM of all module centers at Mitchell Engine Company. Within the group there are LEAN coordinators, one each for commercial & military production, one for validation, and one for test. The function of the coordinator is to link the strategic objectives of LEAN with the business units they

[27] Modified from MIT Sloan School of Management Lecture Slides, Course 15.311 Organizational Processes

serve. Coordinators work directly with each business unit to help them integrate the LEAN tools into their everyday operations.

The implementation of LEAN tools is intended to address both macro and micro challenges. On a macro level the LEAN operating system is intended to improve overall operational performance. Cells and sites have successfully used the system to increase return on sales and deliver engines on time with high levels of customer satisfaction. On a micro level, many of the tools are designed to improve information flow, identify root cause and implement corrective action to problems, and improve EH&S issues. Simply put, if used correctly the system would serve to improve the mechanics work environment, resulting in productivity and quality improvements.

The structural design of the LEAN group may be insufficient given their current roles and responsibilities. With four LEAN coordinators responsible for "coordinating" efforts and influencing change, they seem to be spread thin. There are weekly Kaizen newspaper meetings to engage and keep tabs on cell leaders & managers, and additional meetings with each of the groups they support, but many times tasks related to the LEAN operating system seem to fall in the hands of the coordinators. Some managers and leaders do not take 100% ownership of the tools and use them, but rather assume the coordinators are in place to do the background work supporting the system. One reason for this is the overriding focus on delivering engines, and another is that one could argue that cell leaders and business unit managers are spread too thin to sufficiently focus their efforts on implementing change and using the LEAN tools.

Clearly, the focus on LEAN needs to be brought to the forefront to achieve success. There are cultural barriers to this, but more importantly strategic roles will need to be changed as well. Engagement of cell leaders will be critical, and to that point there needs to be some metrics set that link cell leader performance to the LEAN operating system, fully involving them in the initiative. Additionally I believe these metrics will solve a cultural issue as well, and align their efforts as they cycle through their positions. The design of the LEAN group should change in one of two ways. One way would be to have an LEAN manager & 3-4 coordinators responsible for each of the divisions: commercial production, military production, validation, and test. Part of the reason I feel this way is my own experience and slow pace of change that I have been able to achieve, and I was tasked to focus solely on one assembly cell. The other option would be to keep the existing structure; however, coordination and selection of LEAN Captains who then drive the success of the implementation. Most of the successes of the LEAN system have been in sites where the initiative is driven by the mechanics. In order to attract mechanics to take on these roles, they would need to be given an incentive to overcome the cultural challenges this implementation faces.

5.1.2 Organization as viewed through the Cultural Lens

LEAN was introduced in 1996. LEAN is not the first initiative, as there have been multiple past initiatives. It could be argued that after 10 years and the relatively low success rate that LEAN has underachieved to date.

Until the current president took over, LEAN seemed like just another operating system to both management and the labor unions. Even the metrics that define Green, Yellow, and Red have changed over the years. The pockets of success and relatively low percentage of Green cells were the result of the few managers and leaders who were willing to take on the challenge and influence change, or in operations in crisis mode.

Today, LEAN initiatives carry more weight because of the increased pressure to have every cell & site to Green in two years. Upper management is ultimately responsible for the initiative, and the focus has flowed down through all levels of management. To the executive leaders and upper management LEAN is the operating system that will allow Mitchell Engine Company to maintain or regain #1 or #2 market share in all of their divisions. Middle managers see LEAN as another responsibility, and to some degree something they need to use to be identified for promotion. Some people in the hourly workforce feel threatened by LEAN, afraid it will lead to the outsourcing of their jobs.

The dominant culture that results from the limited success of LEAN is focused on keeping the status quo. Many in the organization continue to execute their daily activities with as if they are doing what is expected of them, not putting the effort or emphasis on changing or fully integrating the tools of the LEAN operating system into their work routine. After ten years of limited success using the LEAN operating system, there seems to be the sentiment that nobody is willing to take responsibility for change within the organization or in the Final Assembly Plant.

Given this, it is logical to look at the cultural risks of taking responsibility. It is unclear who is ultimately responsible for LEAN. Top management in the plant would say all employees are responsible for LEAN. Employees would say their managers must take responsibility and hold people accountable. Middle managers often look to the supporting functions like the LEAN group to drive LEAN within the culture. Ultimately there is an inherent cultural risk to stepping up and attempting to drive change. Most employees have successfully been promoted or have remained employed as long as they maintained the status quo. It seems that the risk of taking responsibility could potentially hinder ones career trajectory while as long as one maintains the status quo, there is no risk of failure within the organization. Until the incentive structure is aligned to promote reward for successful risk taking, the culture will fail to transform to one other than focused on "playing it safe". It seems that as the pressure comes from the top of the organization to drive LEAN throughout that the status quo will no longer be sufficient, forcing many within the organization to become fully proficient in LEAN in order to move up within the organization.

5.1.3 Organization as viewed through the Political Lens

While managers and cell leaders are given formal power to influence change, the mechanics are the ones who have power. It is this reason why many of the change initiatives have only been mildly successful in the past, and also why LEAN has struggled to gain 100% acceptance. While the managers and hourly workers are interested in improvement, the mechanics have no incentive to improve since productivity gain means less overtime pay. One of the necessary changes, in my mind, is alignment of incentives. Mechanics feel that by working with management to adopt the LEAN culture, they would effectively give up power over what they know and how they do things.

There is a long history of discontent between management and labor unions at Mitchell Engine Company, and many would argue that this is one of the largest barriers to effecting change. Additionally, the high cell leader turnover present is the source of some resentment on the shop floor. Shop floor employees view the position as nothing more than a resume builder with those filling the position there for the wrong reason, unqualified to effectively manage the employees. In their experience, it seems that every cell leader has their own individual agenda and incorporates change. The JP-3525 fan case implementation was initially viewed as being no different.

Without daily interaction on the shop floor, their ideas and questions go largely unaddressed. More open lines of communication between the shop-floor and management would fill a large gap in the organization, going beyond the cell leader up through middle and top-level management, hopefully improving the success of change initiatives and sustaining results from existing efforts.

5.2 Role of the Cell Leader in Shop Floor Change

The front line supervisor occupies a unique space within the manufacturing organization, responsible for supervision of shop floor employees. In this role one would assume they play an important part in lean transformation initiatives, which typically focus heavily on shop floor improvements. In actuality, the opposite is often true as cell leaders often fail to truly embrace such initiatives as many choose to distance themselves as far from the shop floor as possible. Many view the role as being stuck in the middle of management and labor, with no identity for itself. In order to understand the actions of the front line supervisor today, it is important to understand the history of the position and how the role has evolved into one in which they must constantly balance trade-offs at the workplace.

5.2.1 History of the Supervisor Position[28]

The supervisor role has evolved over the years and is characterized by a continual decline in power. In small factories, owners were the supervisors. With the division of labor and the growth of factories, owners could no longer handle coordination of activities, and the foreman role was created to lead craftsman. As companies continued to divide labor by functional role, the discretion of the supervisor continued to diminish and by 1940 they were tasked with mostly administrative duties.

[28] Section modified from Klein, "Changing Relations between Supervisors and Employees"

In the 1940's the Foreman's Association of America (FAA) was formed in an attempt to prevent further dilution of their position as well as highlight the difficulties of the position. The 1947 passing of the Taft Hartley Act set the FAA back, ruling that foreman in the private sector did not have collective bargaining power from the "employee" perspective. This Act did much to place the supervisor in the middle of management and labor, a role that had characteristics of both, neither sufficient to be successful.

Attention on the role of the supervisor carried into the 1950's, with specific academic interest on the subject. Through selection procedures and training programs, organizations attempted to improve the role of the supervisor.

In the 1970's employee empowerment initiatives threatened the role of the supervisor altogether in an effort to reduce overhead costs, in conjunction with the greater management belief that work teams could manage themselves. While the supervisor role was not completely eliminated their power base was again diminished as they now had less responsibility over multiple work teams. With this shift it became evident that the role of the supervisor was fundamentally changing.

Today, the supervisor role is seen as much about commitment as it is control. The rise of employee involvement through the 1980's & 1990's including lean manufacturing has transformed the role to one that requires mentoring, coaching, and facilitating a team-oriented environment. The role as it exists today is extremely challenging, requiring the supervisor to exist in the middle of a hierarchical structure and consistently shifting roles between team-facilitator and manager responsible for convincing uninterested employees to change.

5.2.2 Role of the Supervisor – Management Perspective

The evolution of the supervisor at Mitchell Engine Company followed closely to the track described above. In a large manufacturing organization it is common to find the cell leader role in an identity crisis. In turn, there is a degree of confusion as to what exactly the role of the supervisor is on the factory floor, and this confusion is often compounded within the organization.

From a management perspective the cell leader is at the bottom of the hierarchy. Four levels removed from top management, the cell leader is tasked with managing manufacturing activity across multiple production cells broken down by module; for example one cell leader is responsible for commercial fan cases. Management expects them to be involved in fostering relationships with their work teams, responsible for daily communication between management and the shop floor. They are expected to delegate work among production workers in their cell, communicate schedule changes and quality issues with their teams, and discuss improvement initiatives on a regular basis. Top management has a relatively "hands-off" approach in their interaction with supervisors; daily production meetings cover production schedule and issues causing delays. The flow line manager and business unit manager often sit in on daily production meetings.

In addition to the responsibility of managing the shop floor workers to meet schedule, cell leaders are expected to work with LEAN coordinators on continuous improvement activities. The LEAN group is designed to support cell leaders on improvement activities, help coordinate formal kaizen events, and assist cell leaders in using the LEAN tools to improve their asembly cell performance. Weekly meetings are held to discuss progress on improvement initiatives, tracked on a Kaizen newspaper. Many of these tasks are those uncompleted during formal kaizen events, and they are rarely completed on time with the typical cell leader excuse being they were too busy to get around to them.

5.2.3 Role of the Supervisor – Labor Perspective

The role of the cell leader as viewed from the shop floor is much different than the management view. Most mechanics view their cell leader in an administrative role, with minimal involvement on the shop floor. In a survey of the mechanics in the JP-3525 fan case assembly cell it became apparent that shop floor workers had minimal interaction with their supervisors. In their view, supervisors were in place to facilitate the allocation of overtime and arrange use of vacation days. There are numerous factors that lead to this perception of the cell leader.

Many of the traditional duties of the supervisor now occur within the cell itself. The counterpart of the cell leader is the assembly cell lead man. A member of the labor force, the lead man takes responsibility of coordinating activities within the assembly cell. Lead men typically delegate work, arrange part delivery, and address any issues the mechanics encounter during production. In one sense self-directed work teams are functioning throughout the plant, however these teams lack management influence and their actions are misaligned with management goals of the LEAN operating system. The largely autonomous labor force seek to benefit from their actions; for example it is common knowledge throughout the plant that workers slow down during the beginning of the month to ensure overtime is necessary to hit production schedules. Such autonomy undermines management initiatives, such as LEAN, without direct supervisor involvement. Those supervisors that attempt to become more involved are limited by the union contract, and are likely to be met with grievances. Instead they resort to fighting fires as delays in schedule threaten monthly production metrics.

Adding strain to the supervisor-labor relationship is managements' selection of cell leaders. Traditionally, supervisors were promoted from the shop floor, with the best mechanics selected to foreman positions. As the dynamics of the position changed fewer mechanics were interested in becoming supervisors. Today the majority of cell leaders are young engineers who want to gain management experience, or new hires with undergraduate or graduate degrees in 6-8 month operations rotational programs. As a result there are some distinguishing characteristics of those who fill the positions. First, supervisors typically earn significantly less then the shop floor mechanics and have significantly less experience, thus mechanics are not compelled to listen to there "supervisors". On top of this, there is a general sentiment that cell leaders without shop floor experience do not understand the process, what it takes to build and engine, and thus are unfit to manage them. There is some truth to this, unless the cell leader takes the time to understand the processes and the challenges of the job. From a management perspective, the organization puts significant emphasis on the cell leader experience. In order to move up within operations, one must have been a cell leader. As a result, many young people are in the role because they feel they have to, not because they want to. According to the mechanics, the JP-3525 fan case area has had 13 different cell leaders in the past 10 years, many of whom have gone on to top management positions in the company. Many shop floor employees feel as if their supervisors are simply building their resume, spending the minimum time required before they are promoted. The general lack of experience, significantly lower wages, and constant churn within the role translates into a general lack of respect from shop floor workers for those in the position.

5.2.4 Supervisor's Tension

There is a clear disconnect between the expectation and reality of the cell leader. In today's factory environment, the cell leader exists in a conflicting space between management and labor. Often their actions are unknown by management, removed from decision making roles leaving them feeling powerless. Concurrently, cell leaders interested in influencing change are limited by management-labor relations and grievance hearings with decisions that almost always favor the workforce. Finally, many supervisors simply resist employee improvement programs since it threatens their status and personal reward system. Much work has been done on the shifting role of the cell leader over the years. In particular work by Jan Klein will be presented to help the reader better understand the dynamics of the position, and some of the factors that affect their performance in organizations today.

5.2.4.1 Resistance to Employee Involvement Initiatives

As manufacturing organizations increased their focus on programs employing semi-autonomous work teams promoting employee involvement, Jan Klein published her research on the topic in the Harvard Business Review, titled "Why supervisors resist employee involvement" in the fall of 1984. Working within numerous manufacturing organizations, the research focused on the sources of cell leader resistance and postulated that supervisory resistors could be fit into one or more categories.

The article is quick to point out the importance of first-line supervisor involvement in realizing sustainable change in the workplace but also realizes that "if supervisors view programs that increase employee involvement as detrimental to them, they will withhold their support"[29]. Research indicated that rarely is this resistance open but comes out through lack of enthusiasm, interpreted as lack of support for programs. In

[29] Klein, Janice A. "Why supervisors resist employee involvement". Harvard Business Review, Sept.-Oct. 2004, 88

the early 1980's, employee involvement programs were perceived as a threat to supervisors job security, wondering "will supervisors become redundant under a system of participative management?"[30] Another concern was supervisors' job expectation, and how they would be measured, noting that top management typically did a poor job clearly articulating expectations. Research indicated a third concern was that the additional burden of work would fall on their shoulders, and their positions would be a victim of scope creep. The type of resistors identified by Klein are[33]:

- **Proponents of Theory X**: Resist because the concept goes against their belief system.
- **Status Seekers**: resist for fear of losing prestige.
- **Skeptics**: doubt the sincerity and support of upper management.
- **Equality Seekers**: feel that they are being bypassed and being left out of the program.
- **Deal Makers**: Program interferes with one-on-one relationships with workers.

Klein notes the typical management response to these concerns was mere lip service, figuring the resistance was temporary. Some plants tried to sell the ideas through formal and informal mechanisms, telling the supervisors how helpful it would be for their job, building up their expectations, and not realizing these benefits. Overall, communication of these initiatives from top management was poor. Research showed that successful responses to supervisor resistance was typically providing, supporting, and recognizing supervisors for their work, similar to that recognition given to workers. Additionally, in one plant "the crucial action was to delineate clearly the duties and managerial expectations of supervisors – in part by asking them what they perceived their job to be and what they believed it should be."[31]

Finally, the article attempts to formulate a strategy "to make supervisors an integral part of the change process". This strategy included the following:[32]

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[30] Klein, Janice A. "Why supervisors resist employee involvement". Harvard Business Review, Sept.-Oct. 2004, 89

[31] Klein, Janice A. "Why supervisors resist employee involvement". Harvard Business Review, Sept.-Oct. 2004, 92

[32] Klein, Janice A. "Why supervisors resist employee involvement". Harvard Business Review, Sept.-Oct. 2004, 92-93

- **Support-based training**: ongoing consultation with "change-agents" and managers, with managers becoming role-models to show their superiors are committed to a participative management style.
- **Supervisory involvement**: involvement of supervisors in the implementation of employee-oriented programs, giving them a say in decisions that affect their own jobs.
- **Responsibility with authority**: allow the supervisors to gain the self-respect and the prestige in the eyes of their subordinates through enhanced decision-making authority and support.
- **Supervisory networks**: enable supervisors to see the value of such programs by encouraging "peer-networks".
- **Replacement**: management willingness to move supervisors who are unwilling to become involved to "less-damaging" roles.

5.2.4.2 Changing Supervisor-Labor Relationships

Further research on supervisor-labor relationships by Klein surfaced in Chapter 4 of the book Negotiations and Change by Kochan and Lipsky. In this chapter, Klein focuses on the "problematic struggle being caught between multiple roles and having limited control over managing the levers that smooth the transition between fostering team development and forcing hard decisions."[33] Inherent in the supervisor role is the challenge of fostering and forcing issues, which are rarely dealt with or addressed interdependently. Klein uses a strategic framework of Cutcher-Gershenfeld, McKersie, and Walton as a way to better understand the task facing front-line managers. The challenges are laid out in Table 3:

[33] Kochan & Lipsky. Negotiations and Change: Form the Workplace to Society. Cornell University Press, 2nd Edition, 2002. 60

Fostering	Forcing
Building relationships	Picking Battles
Constructing internal consensus	Maintaining resolve
Generating results	Underestimating counter-forcing
Maintaining continuity	Keeping the forcing under control
Anticipating conflicts	Recovery afterward

Table 3: Strategic Negotiations Challenges[34]

These five key challenges form the basis for strategic negotiations, which Klein argues, "provide a framework for this new team-leader role, which recognizes the need to force some issues to achieve effective team-based operations. One of the key lessons is to establish an environment in which teams understand that supervisors will and should force some issues."[35] Based on the strategic negotiation framework, each challenge is broken down to show the interdependencies of "fostering and forcing" as follows[36]:

Fostering Issues

- **Building Relationships**: "team leaders are focused more on building relationships between team members. The challenge is to help team members learn to handle conflicts that will arise and develop a clear understanding as to why and where supervisors may have to step in and force a decision…which is not necessarily a breach of trust."
- **Constructing Internal Consensus**: "good supervisors help their team members understand the linkage between the team's goals and the larger organizational objectives through sharing information and educating team members as to business realities…supervisors view change as an opportunity to realign their team members to the team's objectives."
- **Generating Results**: "supervisors typically have limited ability, other than personal persuasion, to encourage their team members to generate enhanced performance" additional challenges exist when "supervisors must explain why

[34] Cutcher-Gershenfeld, McKersie, and Walton. Pathways to Change. W.E. UpJohn Institute, 1995.
[35] Cutcher-Gershenfeld, McKersie, and Walton. Pathways to Change. W.E. UpJohn Institute, 1995. 61-62
[36] Kochan & Lipsky. Negotiations and Change: Form the Workplace to Society. Cornell University Press, 2nd Edition, 2002. 62-67

market realities reward senior managers with executive bonuses and stock options."

- **Maintaining Continuity**: "a major challenge lies in managing leadership turnover and not reverting to old habits...fire fighting...taking swift action... can be interpreted as traditional supervisory control...supervisors have no control over turnover in middle or senior leadership...the challenge is in managing transitions and buffering their work groups from changes."
- **Anticipating Conflicts**: "conflicts that require traditional supervisory control occur...poor performance at the team level...organizational initiatives often cause conflict at a larger system level...supervisors are usually the first to see the complications, but their input is seldom solicited in the design and implementation of new strategic initiatives."

Forcing Issues

- **Picking Battles**: "when choosing between cutting a deal and using discipline, supervisors must make choices in a manner that builds long-term capability and does not undermine team development...they may not have a choice as to whether they will wage the battle, they typically have a fair amount of discretion in how they package or frame the message."
- **Maintaining Resolve**: "good supervisors...are skilled at translating multiple initiatives into a common theme...they have a long term vision of how they want to develop their team...and ensure that their own commitments can be carried out despite continually changing priorities."
- **Underestimating Counter-forcing**: "supervisors need to step back from the fire fighting to see where counter-forcing may be developing from the bottom up...they need to find an audience to hear their input on where the counter-forcing may occur outside their work group...the root cause of the behavior may lie in a larger system issue."
- **Keeping the Forcing under Control**: "supervisor's primary task is to buffer any negative team effects from higher-level forcing...successful supervisors

have developed norms within their team so that team members do not overreact to situations and openly discuss concerns before they escalate."

- **Recovery Afterward**: "strategic supervisors provide as much advance warning as possible to their team members to cushion the forcing. In this regard, recovery is highly dependent on the extent to which there are clear and accepted expectations that forcing will occur at times…fostering team development and forcing issues are tightly coupled."

The interdependencies of fostering and forcing are real and need to be addressed in supervisor roles, though most companies fail to recognize this need in their selection process and training programs, which often only address one or the other. Discussion of these challenges helps frame the "current state" of the cell leader and gives a framework for what the "future state" should aspire to be like. "In both roles, their objective is to build mutual respect and trust between management and labor and among team members within their team."[37]

5.3 Improving Cell Leader Involvement & Impact

Involvement and commitment of first line supervisors is necessary to achieve successful lean transformation. Examples from the Toyota Production System, the Lean Aerospace Initiative, and industry call on the involvement of management to successfully lead change. In the case of Mitchell Engine Company it is no different, and the success of the initiative hinges on the leadership of senior management. Since the cell leader is in the position with the greatest lever to effect change, it seems logical that management focus should improve their standing within the company. Based on some of the shortcomings of the current state of the cell leader role, the following steps could help transform their position and thus accelerate the efforts transforming to lean.

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[37] Kochan & Lipsky. Negotiations and Change: Form the Workplace to Society. Cornell University Press, 2nd Edition, 2002. 67

5.3.1 Management Commitment & Involvement

Looking at the current state of the cell leader role there is a need to start rebuilding trust and respect through direct involvement of senior management in the Final Assembly Plant. With current president of Mitchell Engine Company committed to change and providing the funds necessary, it is a huge opportunity for the plant manager, product line directors & managers to reinforce the importance of the cell leader position and give them the support necessary to succeed.

First, management needs to clearly and consistently communicate with first line supervisors what is expected of them in their roles. In this process, management should work to ensure that cell leader performance metrics are aligned with the goals of the initiative, and look at ways to fully utilize their unique position within the company to make an impact, perhaps limiting their administrative tasks. Should cell leaders be measured on delivery targets, should performance be based on their use of the LEAN operating system tools, or perhaps both? It is important to understand how improper metrics can cause cell leaders to take actions inconsistent with lean principles.

Once the expectation is set and metrics are clearly defined, management in the middle of the organization in the plant will need to take responsibility for executing the cell leader role change. Both product line managers and flow line managers have direct authority over front line supervisors, and thus have the greatest influence on the position as well as their status on the shop floor. This is no short order; significant effort is required to rebuild trust and respect. Honest and consistent communication of the business challenges is necessary, creating a sense of need for the LEAN operating system in the organization. In addition to communication, direct involvement in activities related to the lean initiative shows support for the initiatives and can help rebuild the status of the cell leader, but it can also diminish it if not handled properly. In numerous organizations, direct involvement of plant management and directors was common in shop floor lean improvements. There is opportunity to involve product & flow line managers as well as product directors in formal kaizen events and value stream mapping exercises, sending a strong message to the workforce about the importance of LEAN. Having once filled the position themselves, managers within the organization should be aware of the difficult role cell leaders fill, and ensure their actions are consistent with supporting and improving their status among the workforce.

5.3.2 Enabling Front Line Supervisors to Succeed

There are numerous barriers that prevent front line supervisors from succeeding in organizations. Lack of trust and respect are one example which results in little to no status among their subordinates. Cell leaders are currently lacking the "forcing" aspect their position requires for success. The union contract governs the amount of "forcing" the front line supervisors are formally allowed. Thus the focus should be placed on how to properly train cell leaders on the tools available that give them influence over the group.

The grievance process that often arises when front line supervisors attempt to force issues on the workforce is undesirable for both management and the union leadership. Typically labor negotiations and negotiations in general result in suboptimal results for one of the involved parties. In the case of such negotiations, at times the result may seem suboptimal to the cell leader, while the organization as a whole benefits from the negotiation. It is difficult to satisfy everyone involved, however the Final Assembly Plant should look at ways they can optimize labor productivity. One action that would supplement efforts throughout Mitchell Engine Company in implementing LEAN would be to formally include it in the union contract. While this in itself is certainly not a solution, it prevents shop floor workers from directly preventing LEAN initiatives, a power they currently hold.

Management at Mitchell Engine Company can also support front line supervisors in regaining the forcing aspect of the position by providing better training and coaching on how to build a discipline case that will hold in the grievance process. In reality, it is possible to successfully build a case, though most cell leaders don't have the skills or know how to do it, and those that do often fail to put the time and effort into building a strong case.

The irony surrounding the current situation is that both management and the union leadership would benefit from successfully disciplining some of the individual poor performers on the shop floor. Front line supervisors often felt as if their hands were tied when dealing with these individuals, while the union stewards had the responsibility of representing their cases even if they agreed with management. Giving the cell leaders proper training on how to build a strong discipline case would be an avenue on how to deal with such employees, and as a benefit will please the union stewards by alleviating the burden of these employees on the labor force.

Additionally workers need to understand, and many do already, that some level of discipline is necessary to enable effective team-based operations. In fact many of the best workers in the plant communicated that they wish management would take the steps to discipline non-performing co-workers. Training and coaching front line supervisors on building a strong discipline case would help build some of the trust and respect that is missing from the position.

There are some reasons why front line supervisors fail to put the time and effort into building a strong discipline case even if they know how to do it. First of all building a strong case takes quite a bit of effort to document employee misbehaviors and creating a long paper trail of evidence. This effort is often above and beyond the everyday tasks a cell leader is responsible for and they do not appreciate extra "administrative" work. In addition to the effort it takes in documenting, building a strong case could take a number of years. As I will discuss in the next section, many cell leaders rotate through the position fairly quickly so it isn't guaranteed that they will realize the benefit of their effort in building a case.

These issues can be addressed in multiple ways. The issue surrounding the effort it takes to build a case must be considered when the responsibilities of the front line supervisor are determined by management as discussed in the previous section. The issue surrounding the time it takes to build a case can be addressed by reducing turnover within the position, or putting a centralized system in place to track and manage employee discipline cases that is recognized and supported by middle management within the organization and communicated during transitions between front line supervisors. Another reason that supports centrally managing discipline cases within the organization is that often the individuals involved in discipline cases rotate positions within the factory, making their actions difficult to track at the supervisor level.

5.3.3 Improved Cell Leader Selection & Reduced Turnover

Careful selection and hiring of cell leaders can improve the effectiveness of the position on the shop floor. Better selection of cell leaders can be helpful in two ways; minimize the mentality of the cell leader position as a career stepping stone, and also avoid the tendency to place only employees with little management experience and minimal experience with LEAN into the position.

Selection of employees into the cell leader position must strike a balanced mix of seasoned, veteran employees promoted from the shop floor combined with new recruits with management experience. On one hand, the experience gained as a cell leader is valuable to the new recruits however they cannot just be thrown into the position without guidance. By mixing new recruits with veteran employees from the shop floor they will have a direct resource to facilitate success. Seasoned shop-floor employees have a wealth of knowledge and experience about the product and processes, and often have the trust and respect of the workforce. This combination along with the ability of the new recruit to form a close relationship with their counterpart will immediately give them some credibility, helping them make a smooth transition into the role. While the correct mix of employees to fill the positions depends largely on the company itself, it seems that Mitchell Engine Company should shoot for a balance of approximately 60% new hire, 40% seasoned shop floor veteran. In my limited experience, it is my intuition that the company has lost a critical balance in this regard with far too many new recruits with little or no shop floor experience filling the positions. For example in the cell I was most involved with the 2nd shift cell leader was promoted from the shop floor, but he had a relatively short tenure as a mechanic and didn't seem to have the respect of his peers. The organization could benefit from identifying and enticing some of the promising young mechanics who earned the respect of their peers by working directly with them early on to discuss the option and benefit of moving into a supervisor position.

Attracting experienced workers from the shop floor will be a difficult task. Open communication with top management and restoring power to the position would change the perception of the position, potentially improving its attractiveness. Additionally there will be issues with pay as well, as currently even the lowest tenure shop floor workers take home higher pay than front line supervisors when overtime is included. Convincing someone to take a management position that will result in decreased pay is a tough sell.

Reducing the layers of management so that cell leaders had more authority, potentially higher pay, and more direct access to senior management in the facility improve the attractiveness of the position. This would improve communication and further serve to reinforce commitment and status on the shop floor. At the same time steps should be taken to reduce turnover within the position. While new recruits will still be used to fill the positions, make it clear they are expected to stay long enough to influence significant change. Given the time and effort it takes to build relationships with subordinates and acquire comprehensive knowledge of the product and processes it is likely to require a minimum of two years time in the position. Longer tenures will also improve their willingness and ability to build strong discipline cases as they are more likely to realize the benefits of their efforts, one aspect of a solution to a larger problem outlined in the previous section. Perception of the position as a stepping stone among shop floor employees will be minimized with longer tenures as well, adding some credibility to the position and respect to the employee filling it. There are advantages to this in the long run as mechanics see their past cell-leaders move up through the organization, they are more likely to be remembered for what they achieved rather than how quickly they came and left. As a trade-off there is greater pressure on management to monitor cell leader performance if longer tenures are expected. Middle management has the responsibility to address ineffective front line supervisors and move them to positions of less importance within the organization.

5.4 Systemic Change within the Organization

Changing the role of the cell leader in the organization will require systemic change. This change needs to address many of the current gaps outlined in this chapter. In addition to some of the issues covered, a clear reward system must be put in place as well, potentially including career ladders so that cell leaders have a better grasp on how the experience fits into their overall career development plan. Finally, the new role justifies giving cell leaders additional resources including possibly budget authority. Giving them greater ownership of the cells they are responsible for provides decision making authority that can directly address workers needs and restores some power and respect to the position. Additionally budget authority may increase the rate at which improvements are implemented, building further respect with shop floor employees.

Chapter 6: Conclusions

"If you go into an organization and bring the people who work there the glad tidings that you are going to change what they do, how they do it, who they do it with, how they are measured, how they are paid, how they are organized, and even what goes on in their heads, their response is likely to be utter panic."[38]

With lean manufacturing efforts the focal point of many U.S. manufacturing organizations, leadership will continue to be challenged with the prospect of managing change. Whether the efforts are in place to increase shareholder value or to improve the competitiveness of the organization in the face of an increasingly global marketplace, successfully transforming operations to lean is a key aspect determining success. In the US aerospace industry in particular, there is huge pressure in the commercial sector to reduce costs, improve quality, and deliver product the customer values on-time. The ability of manufacturers such as Mitchell Engine Company to maintain significant industry share in the market is directly correlated to their ability to successfully transform to lean.

6.1 Applicability of Work to Other Industries

In addition to providing background and basic approaches to lean in various organizations, it was the aspiration of the author to encourage the reader to think about the role the front line supervisor plays in organizational change and ways in which the position can be leveraged to improve the chances of success. Although many of the examples put forth in this document are based on experiences at Mitchell Engine Company, it is clear that any manufacturing organization with strong union influence could benefit from the recommendations in this thesis. The existence of less than ideal management/labor relations is something that permeates all industries, and is not likely to change in the near future. Taking steps to improve management effectiveness within the

[38] Michael Hammer and Steven Stanton, The Reengineering Revolution, (New York: Harper Business, 1995), 122

constraints of these agreements is necessary to ensure the success of shop floor change initiatives.

In addition to companies in the manufacturing sector, it seems that applying the principles of lean manufacturing can be an effective approach to improving operating efficiency in other industries. The Mitchell Engine Company provides a perfect example of the flexibility of lean principles using the LEAN operating system across all of its operating companies and within of all its business units. The lean based tools have proven effective in both manufacturing and service based operations. Throughout each of the organizations, LEAN tools have proven successful in various departments as well, with finance, engineering, purchasing and marketing realizing process improvements and efficiency gains.

6.2 Recommendations for Further Research

Based on the experiences of the author and the research conducted on various lean approaches, there are numerous initiatives that could continue on the heels of this thesis. Some potential future projects are:

- From an organizational standpoint, conduct specific research focusing on the systemic change necessary to change the role of the cell leader. Developing metrics, rewards, incentives, and criteria for hiring for the cell leader position would be a logical output in addition to determining how the change in cell leader role affects the metrics/incentives/reward systems for those in the layers of management above the cell leader.
- Focus on putting a process in place to implement LEAN initiatives on the shop floor. Although LEAN preaches standard work, the actual implementation of shop floor improvements could benefit from a structured process. While kaizan events are used to identify opportunities, once these opportunities are identified specific steps on how to execute on improvement projects do not exist. The intent of this effort would be to improve on the cycle time of the improvement initiatives.
- Develop a tool that allows more effective communication between the shop floor and senior management. This tool should focus on providing insight to

the shop floor workers on how their actions directly affect the performance of the business. Linking the Performance Sheet metrics and performance data to the daily activities of the mechanics providing clear signals of how their performance affects the business in real-time may result in a more empowered employee base with a greater sense of responsibility and accountability for the factory's operating performance.

6.3 Concluding Comments

The increasing global marketplace has put pressure on traditional US manufacturing firms and their managers to find innovative ways to cut costs. Often their first inclination and the recent trend is to move manufacturing to low cost countries however this is not without risk, both politically and economically. Productivity and quality are but two of the primary concerns when making such decisions.

Another natural tendency promoting the flow of manufacturing jobs outside of the US is the tendency of developed economies to continually move from manufacturing based economies to an economy based on service. This trend is clearly evident in the United States, as many of the traditional US manufactures now focus heavily on service operations as a key area of revenue growth.

However, some industries are likely to always remain in the US, and companies such as Mitchell Engine Company may feel a level of protection from outsourcing. Military aircraft engine programs play a strategic role in the national defense of our country; however the potential to outsource this production is a real risk as engines are being developed for use by multiple countries, by a consortium of companies, with each country involved in different aspects of the manufacturing process. With the general trend in manufacturing towards globalization those managers and employees who rely on the survival of the industry must take steps to curtail the rate manufacturing jobs are being outsourced to ensure their own job security.

Mitchell Engine Company is currently using lean principles to remain competitive in a global marketplace. Their ability along with those of other US manufacturers to consistently identify gaps in the organization and make the difficult decisions necessary to affect change is critical to the future success and sustainability of manufacturing in the

United States. Such efforts, perhaps the most difficult and time consuming, will ultimately provide the greatest reward.

Disclaimer

All conclusions made in this document represent the author's personal views, and not necessarily those of the Massachusetts Institute of Technology, the Sloan School of Management, the Leaders for Manufacturing program, Mitchell Engine Company, or any of the individuals associated with these organizations. None of these entities expresses or implies any warranty or assumes any legal liability or responsibility for the accuracy, utility, or completeness of any information disclosed.

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