

## THE LEAN JOURNEY AT THE BOEING COMPANY

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### SUMMARY

This paper chronicles the history and development of a Lean Enterprise at The Boeing Company. Over two decades, Lean tools have been developed and the culture of the workplace has evolved through education and hands-on involvement so that now, Lean is part of the Boeing culture. The key environmental factors that helped Lean succeed will be discussed. The tools that were emphasized at each stage of development will be shown.

### INTRODUCTION

This presentation shares the road taken at The Boeing Company toward a Lean Enterprise. As early as World War II, Boeing employed methods to build the B-17 that would be considered Lean today. The driving need for planes and the restricted resources for manufacturing necessitated streamlined processes with minimum waste. The sense of urgency faded after the war, and so did the use of Lean methods. In the mid 1980s Boeing began its Lean journey with the introduction of Quality Circles or Productivity Circles. This was followed by World Class Competitiveness training, 5S, and Just-in-Time workshops. Learning to use individual Lean tools like accelerated improvement workshops, or AIWs, provided the foundation on which Boeing Commercial Airplanes created an integrated Lean strategy. The whole of The Boeing Company was embracing Lean by 1999. The strategy for becoming a Lean operation is called the 9 Tactics. A visual representation to show the entire company how all the elements of Lean fit together has evolved. Based on the Toyota Production System, it is called the Boeing Production System.

Management support was crucial to the success of this cultural evolution, and was generated by passionate champions and the external pressures of ramping production and of government contract changes. The contributions of different consultants and champions will be discussed.

### BACKGROUND

Where did Boeing stand? What had they instituted, as they began the Lean journey? In World War II, the Boeing company built B-17 Flying Fortresses for the U.S. Army Air Force. The first prototype went from design board to flight test in less than 12 months. The country needed as many B-17s as Boeing could build, as fast as they could build them. Half of the workforce was women, new to manufacturing. With the driving need and the fresh eyes, many methods that we now call Lean were developed. For example, there was no room in the factory, so movement and inventory were minimized. U-shaped multi-lines and kitting were used. Major subassemblies were completed and then assembled into the final plane. A giant clock governed the flow of production. Output soared, up to as many as 15 planes a day. After the war, the sense of urgency ended. Waste crept back into design and manufacturing processes.

At the start of the 1980s, Boeing was organized into two groups, Commercial Airplanes, and the military side, Boeing Aerospace. Both groups were implementing quality improvement approaches. Commercial Airplanes had presentations from Dr. Edwards Deming, and 3,000 managers studied his book on management *Out of the Crisis*. In groups, they identified top barriers to quality. Quality guru Dr. Joseph Juran spoke at Boeing Aerospace. Quality Circles and Productivity Circles were instituted to improve employee involvement. Around 1983, John Black developed the Employee Involvement program that shot out of the gates at the 757 program. In 1986, Commercial Airplanes formed the Quality Improvement Center.

### THE ORGANIZATIONAL DEVELOPMENT COMPONENT

A culture of teaming was developed, with employee training across Puget Sound focused on team skills. By the early 1990s this effort was focused through the Continuous Quality Improvement (CQI) Associates program on the commercial side of the house and through the CQI Specialists program on the aerospace side, which had been renamed

Defense and Space Group. Both of those programs were dismantled for cost savings reasons in the mid-1990s. The rationale was that there was a base of trained people, and that the programs could declare success. That was when they learned that when leadership backs off, so does the workforce.

## **THE STATISTICAL PROCESS CONTROL COMPONENT**

In the mid-1980s The Boeing Company embraced statistical process control (SPC). By the early 1990s, Puget Sound Military Airplanes management was decreeing that all processes have SPC charts. Quality Circles morphed into SPC teams, and employees learned to use data to improve processes. The corporate driver was that the government had stopped “cost-plus” contracts. Boeing no longer was guaranteed a certain profit for each contract. They had to reduce costs to maintain or increase profits. Variability reduction efforts were coordinated across the Defense and Space Group. Commercial Airplanes used an initiative called Hardware Variability Control.

## **CONTINUOUS QUALITY IMPROVEMENT MORPHS TO ACCELERATED IMPROVEMENT WORKSHOPS**

Boeing was just starting production of the next-generation 737, and the sheet metal shop in Commercial Airplanes could see that they would not be able to handle the demand with their existing capacity. A benchmarking trip to General Electric had shown them a method for managing rapid change called Workout. They hired DeltaPoint, a consultant company, to help develop GE’s Workout into Boeing’s JIT Workouts, one week blitz workshops. JIT Workouts would evolve into Accelerated Improvement Workshops (AIWs).

In the early 90s, Craig Habakangas and Don Larson in the Boeing Fabrication Division conducted the first AIW. There were subsequent AIWs conducted by interested groups around Fab Division, leading to localized improvements. Boeing began learning the tools. John Black participated in an AIW and wanted to take them company-wide. He hired Craig Habakangas and Dick Bowers, who worked with DeltaPoint to change the JIT Workouts into AIWs.

At Arnprior, a Boeing Fabrication facility in Canada, Bruce Gissing, Senior Vice President of Continuous Quality Improvement, started implementing the Just In Time (JIT) flow management system. Arnprior has since gone on to become a Lean leader in The Boeing Company, winning the Fred Mitchell Award for Lean Manufacturing Excellence three times in a row, from 2001 to 2003. Another Commercial Airplanes Fabrication Division site, Wichita began to use JIT in 1995.

## **JAPAN STUDY TOURS AND WORLD CLASS COMPETITIVENESS**

The first Japan study tour, in which top managers visited Japan and benchmarked eight different companies there, took place in 1990. Each company visited was “world class” in something. Bruce Gissing, then senior vice president of Operations in Commercial Airplanes, and Bill Selby, of Boeing Aerospace, led trips to Hitachi, Komika, Toyota and others. The top managers who went on the first Japan study tour included the director of World Class Company Studies for Boeing Commercial Airplanes, the director of International Business Operations for the New Airplane Division, the vice president of Operations Development, the vice president/general manager of Fabrication Division, the senior manager of International Business, and the vice president of Engineering. Preparation for the trip included 45 hours of classroom training, and reading five books. The actual trip lasted two weeks.

The support for this major expense and effort was probably generated because Boeing Sales had sold more airplanes than the factories had ever built in a year, and senior management could see the brick wall looming as production tried to meet the demand. They also saw Airbus capturing McDonnell Douglas’ share of the market, and could see that Boeing was next. Airline deregulation had cut profits for Boeing’s commercial airplanes customers. The demise of cost-plus contracts had a similar effect on the Defense and Space Group’s business. Senior managers realized that they needed to begin the journey to make a better company.

This first Japan study tour was significant. Without it, Boeing would not have launched the major World Class Competitiveness initiative that followed. The approach was developed in a thoughtful, planned manner. Management realized that transplanting Japanese methods would not work without adapting them to the Boeing culture.

World Class Competitiveness training for all Boeing employees came next. It was developed as a way to implement the learnings of the Japan study tours. Many managers believed that just because Boeing had the largest market share, Boeing was “world class”. Metrics showed that they were not. Bruce Gissing hired DeltaPoint, the consultants who had helped Boeing develop JIT Workouts, to help Boeing develop this training. It was delivered by Boeing managers in Commercial Airplanes and in the Defense and Space Group to more than 100,000 employees over a one-year period.

5S was the next corporate push, which may be the first corporate-wide step that was recognizably Lean. The 5 S’s are Sort, Simplify, Sweep, Standardize, and Self-Discipline. Every area was required to progress from level 1 through 5 of 5S. Massive amounts of material were surplus, recycled, or otherwise removed from areas. The Boeing Surplus Store in Puget Sound became a great shopping place for the public. Work processes became documented and standardized through 5S

team meetings in office and factory areas.

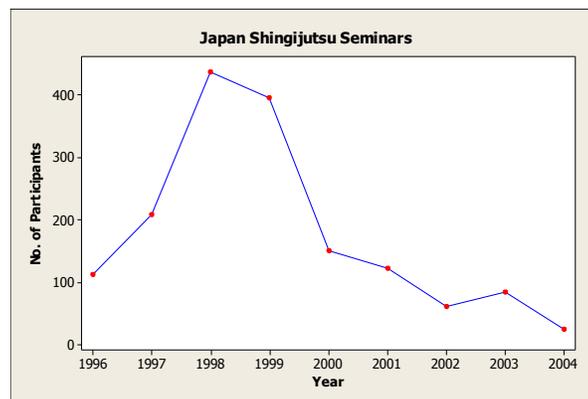
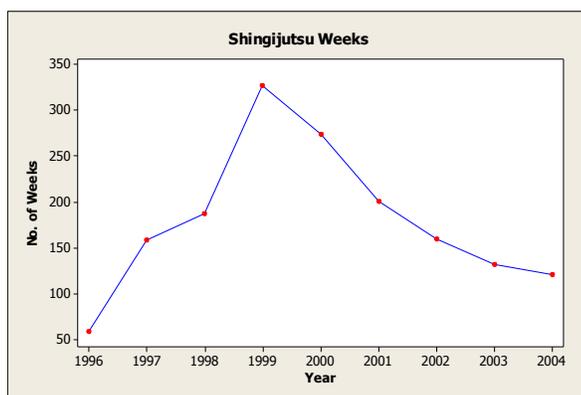
The perception at the time was that 5S was a stand-alone initiative. Other parts of Lean, such as Just-In-Time Manufacturing, were also seen as stand-alone initiatives, competing with each other, rather than as parts of a Lean production system.

At Propulsion Systems Division (PSD), Dennis Racey, who later would head the Lean Manufacturing Office, was earning his MBA. He asked Carolyn Corvi, their vice president, for a big project to work. She said he could implement Lean at PSD, one of the first places to have a full-blown implementation strategy. It was a good place to start, since they could control their own engine buildup process. Boeing only needed two engines a day, yet they had 27 to 30 engines in the backyard - just-in-case inventory. PSD hired Booz Allen Hamilton to help with their Lean assessment. A key to their success was having Corvi as sponsor. The result of implementing Lean was reducing inventory holding costs and shortening the production flow needed to assemble an engine from ten days to one day.

John Black, Craig Habakangas, Mike Ralston and Don Blake visited Wiremold, a supplier known for excellence at Lean practices. Art Byrne, Wiremold CEO, was one of industry's strongest champions of Lean. Bob Dryden, a vice president at Boeing Commercial Airplanes, had a contact at Pratt & Whitney aircraft engine company. Wiremold and Pratt & Whitney both used a Japanese consulting company called Shingijutsu. Shingijutsu was founded by protégés of Taiichi Ohno, father of the Toyota Production System. The Boeing people participated in Wiremold/P&W workshops, and met Shingijutsu senseis Iwata and Nakao. Bob Dryden agreed to contract with Shingijutsu consultants.

The first Shingijutsu Japan Kaizen seminar Boeing attended occurred in 1995. Boeing managers traveled to Japan once more, this time to study Toyota's production system (TPS). Most manufacturing companies recognized that TPS is the most elegant model of performance and growth.

From 1995 to 1998 Boeing focused on conducting AIWs. In the first two months of 1997, Commercial Airplanes conducted over 100 AIWs. Fred Mitchell, vice president of Manufacturing, consolidated the various lean efforts into one office. In 1996 Boeing formed a central Lean Manufacturing office under John Black to focus on strategy across Boeing Commercial Airplanes. Shingijutsu consultants spent many weeks at Boeing and hosted many senior managers at Japan Kaizen seminars.



The component factories embraced Lean as a way to overcome constrained manufacturing capacity during the violent rate ramp-up of the mid-1990s. They learned that until Final Assembly reconfigured their processes to Lean manufacturing, Boeing's Lean efforts could never be completely successful.

After several years of AIWs, Shingijutsu consultants started showing Boeing other tools, such as distribution kaizens, Production Preparation Process (3P) workshops, and Heijunka. Boeing also began benchmarking Toyoda Boshoku, the company that best demonstrates those principles. As Boeing has matured, they have not required as many weeks of Shingijutsu consulting, nor do they send as many managers to Japan Shingijutsu seminars as they did in 1998 and 1999.

Wencil McClenahan benchmarked General Electric Aircraft Engines (GEAE) for their Six Sigma methodology when Boeing and GE agreed to produce the 777 Long-Range airplane with only GE90 engines. Boeing Commercial Airplanes launched Six Sigma in 1999, and developed their own training the following year. In 2001, Dennis Racey's Lean Enterprise Office absorbed BCA Six Sigma. At the end of 2002, BCA had merged their Six Sigma program with the Integrated Defense Systems' Boeing Navigator program.

Lean became a formal push on the military side in 1999. Jan Martinson started the Lean Enterprise office in Space and Communications headquarters, and Jim Davis implemented one in Aircraft and Missiles headquarters. Commercial Airplanes had changed the name of the Lean Manufacturing Office to the Lean Enterprise Office a year before that, to emphasize the importance of non-manufacturing processes. The shift of focus was from manufacturing to the program level. Martinson and Davis are focusing on the 'white spaces' between Operations, Engineering, and Supplier Management.

## **BOEING COMMERCIAL AIRPLANES STRATEGY ROADMAP - THE 9 TACTICS**

Enter Mary Dowell, another avid supporter of Lean. She ran 737 Final Assembly, where, in 2000, they developed the roadmap to achieving continuous flow that Boeing calls the 9 Tactics.

Tactic 1 Value Stream Mapping  
Tactic 2 Balance the Line  
Tactic 3 Standard Work  
Tactic 4 Visuals in Place  
Tactic 5 Point of Use Staging  
Tactic 6 Feeder Lines  
Tactic 7 Process Breakthrough Redesign  
Tactic 8 Pulse Line  
Tactic 9 Moving Line

Where does Boeing use the 9 Tactics? Final Assembly and components in 717, 737, 757, 747, 777, 767, AH-64 Apache, C-17, IRC, Wings Organization-Everett and Renton, F/A-18, and many other areas

### **POINT OF NO RETURN – 737 MOVING LINE**

The 717, manufactured in Long Beach, California, implemented a pulsed line for Final Assembly in November 2000. It was the first time that this automobile production technique had ever been applied to airplanes. Michael Graziano was the Boeing leader who made it happen. It took another year, until September of 2001, to get to tactic 9, a moving line. The 737 program in Renton, Washington, implemented their moving line for Final Assembly in April of 2001. The 757 line, also in Renton, started their moving line in August 2002. Other commercial airplane programs are well on the way to moving lines. Boeing also has moving lines for major subassemblies, such as the F/A-22 wing assembly in Kent, Washington.

### **CORPORATE LEVEL INVOLVEMENT – THE COFFEE GAME AT THE BOEING LEADERSHIP CENTER AND PAT TEAMS**

About the same time that the 9 Tactics were being developed, Lean was being deployed across the enterprise. Boeing had three primary business units, Commercial Airplanes, Aircraft and Missiles, and Space and Communications. All the managers in this huge merged company are trained together in St. Louis at the Boeing Leadership Center. The Coffee Game was developed for the Boeing Executive Program. It is a simulation of the entire Value Stream, from coffee growers, through roasters and transportation companies, distribution and finally, to coffee drinkers at the Boeing Leadership Center. A primary lesson is the importance of cooperation between suppliers and customers. This Coffee Game has since been incorporated in the Boeing Six Sigma Black Belt Navigator training at the Leadership Center.

The Boeing Operations Council (BOC) formed a Process Action Team (PAT) for Lean. They have regular face-to-face meetings as well as frequent virtual meetings, to share ideas and plans. They make sure that training is standard across the enterprise, and strive for the Lean ideal of standard work.

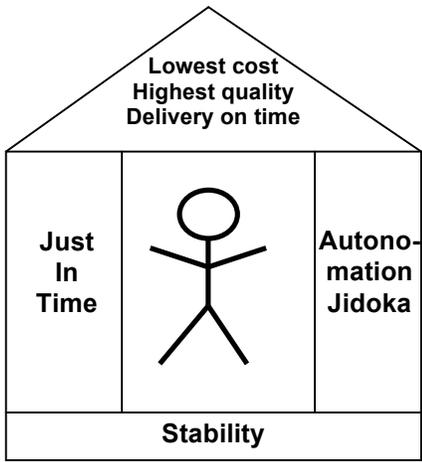
### **FOCUS OUTSIDE THE FOUR WALLS**

The last several years have seen Boeing look outside its four walls, training suppliers and customers. Jim Davis, the Lean leader who started the Aircraft and Missile Lean Enterprise Office, is consulting with military bases. When Boeing outsourced the insulating blanket shop from Fab Division to Mexmil in Mexico, the Commercial Airplanes Lean Enterprise office had to provide Mexmil Lean training in order for them to meet Boeing's requirements. Now Boeing and Mexmil are working together to develop a "Toyota-Boshuku"-type Lean implementation. Mike Herscher's Commercial Airplanes Lean Enterprise Office is offering its expertise to commercial airlines. The Field Service organization has been working joint Six Sigma projects with airline customers. The belief is that if customers are more successful, they'll buy more aircraft, parts, and services. If suppliers are successful, Boeing will have a more efficient and cost-effective production flow.

### **FROM THE TOYOTA PRODUCTION SYSTEM TO THE BOEING PRODUCTION SYSTEM**

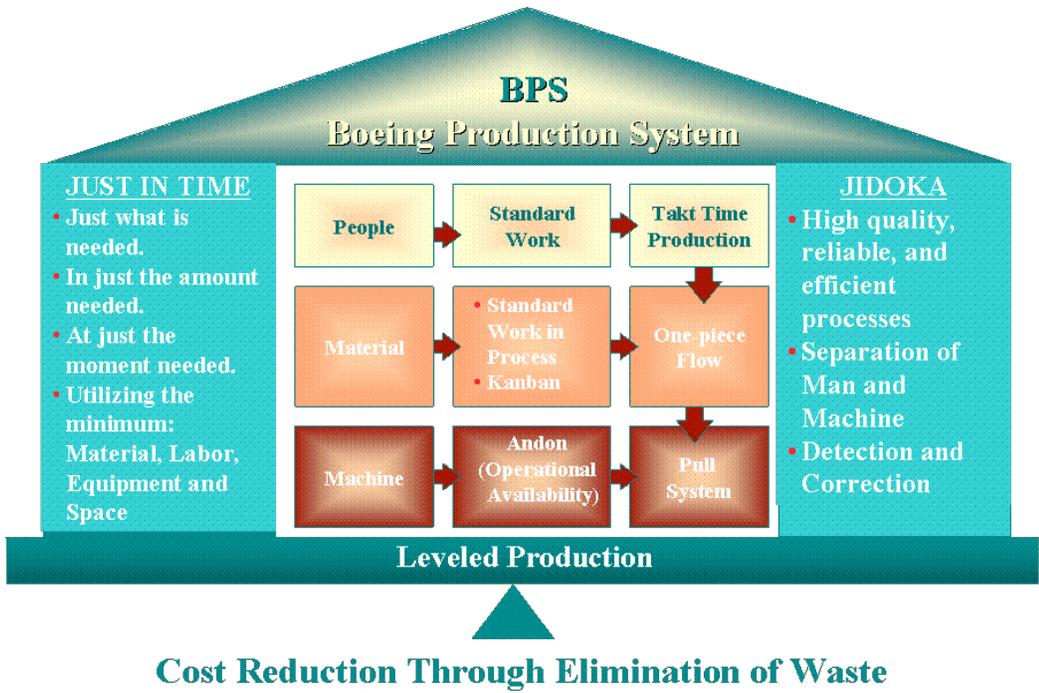
Toyota uses a visual display to show how all the elements of a Lean production system fit together. They call it the Toyota Production System (TPS), shown below. It looks like a house, with a roof, two pillars on the left and right, internal

structure, and a foundation.

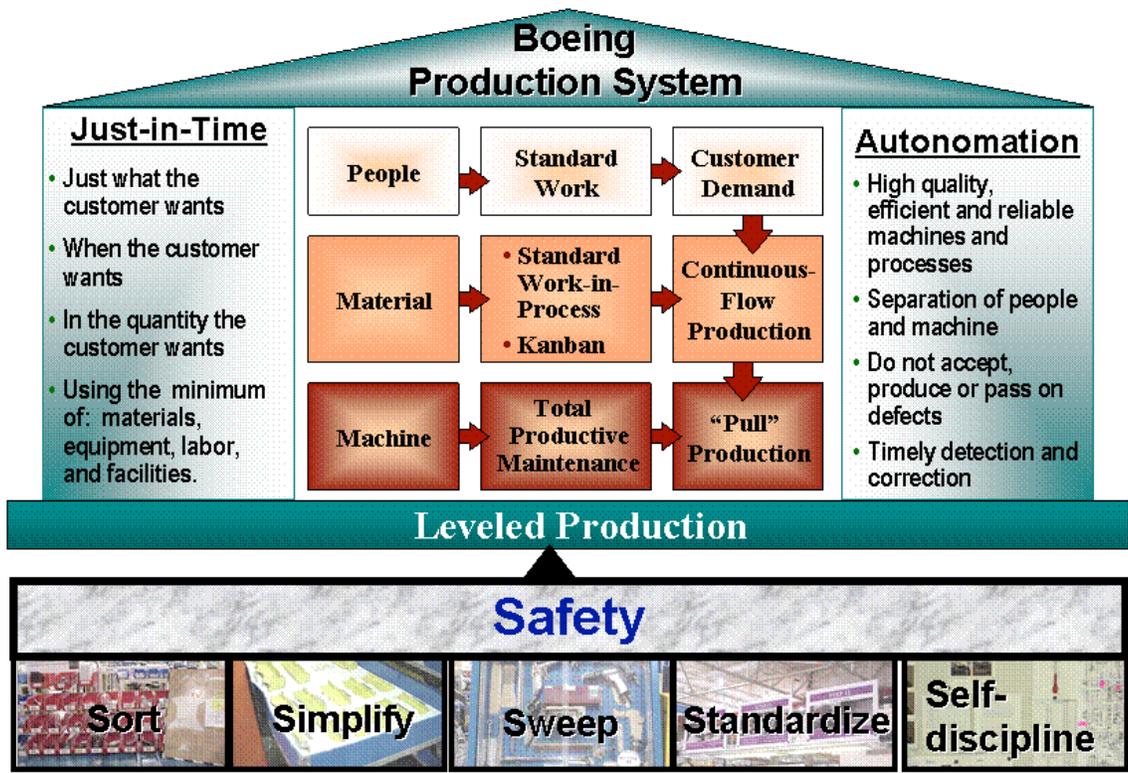


Boeing, like other companies that are incorporating Lean, customized the TPS house into the Boeing Production System (BPS) house. This visual aid showed the entire company how the various pieces of Lean all fit together. The images below show how the BPS house evolved over the years.

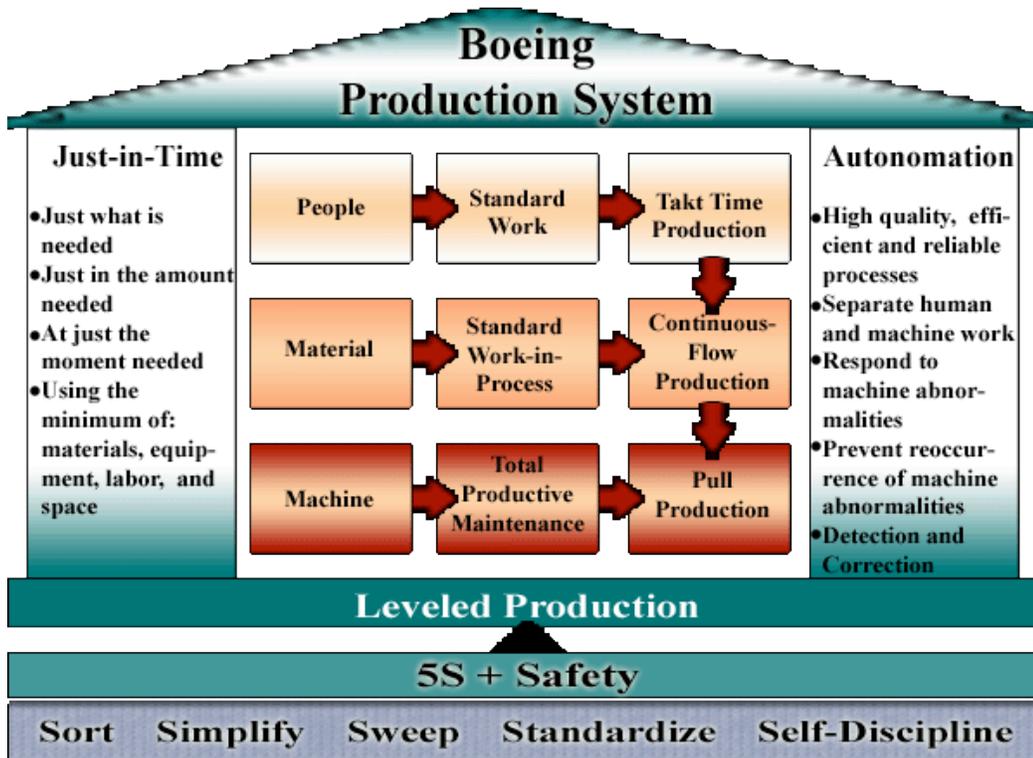
In 2000, it had a fulcrum and the nine internal blocks as a guide to developing toward a “Pull System” of production.



By 2003, the base had been expanded to emphasize 5S as the foundation of the BPS house. A bullet was added to the Autonomation pillar which is repeated regularly at Boeing: Do not accept, produce or pass on defects.



The latest version of the BPS house re-emphasizes the elimination of waste in the foundation.



The Boeing Production System (BPS) is based on the relentless elimination of waste to reduce costs, shorten lead times and improve quality for the purpose of increasing customer satisfaction.

Boeing departed from the Toyota model when they developed the Tailored Business Stream (TBS) approach. TBS divides Commercial Airplane products into three 'streams', to arrive at simpler, more usable, cost-effective processes and solutions. Instead of designing and producing every airplane as if it were unique, they now divide all the elements of work (e.g., parts, processes, activities, data) into three categories: Basic and Stable, Reusable (including available options), and Custom.

## TIMELINE

- World War II – B-17 production in Seattle
- 1980 – Quality or Productivity Circles in Fab Division
- 1984 – Dr Juran at Boeing Aerospace Company
- 1986 – Dr Deming at Wichita, Conway Seminars
- 1990-1991 – Japan Study tours, CQI as management system
- 1992 – World Class Competitiveness (WCC), 5S, Arnprior JIT
- 1993 – Fab and PSD division JIT, Accelerated Improvement Workshops in Fab
- 1995 – Wichita JIT
- 1995 – First Shingijutsu Japan Kaizen Seminar (ongoing, with evolved subject matter)
- 1996 – Lean Manufacturing Office formed from old Quality Improvement Council (Boeing Commercial Airplanes)
- 1997 – Boeing/McDonnell Douglas merger. Aircraft & Missiles starts Lean Manufacturing Office, followed by Space & Communications Lean Manufacturing Office the next year
- 1997 – Moving Lines initiated in Commercial Airplanes. Point of Use pilot.
- 1997 – Boeing Supplier Consulting group formed in Materiel Division
- 1998 – Supplier / Customer joint improvement activities
- 1999 – Moonshine groups formed, 3P activities including chaku-chaku and Right-Sized Equipment, Distribution Kaizen events
- 1999 – Mark Weltman created a centralized Lean organization on the military side of Boeing.
- 2000 – Six Sigma, Value Stream Alignment, Single source of data warehouse, 9 Tactics developed

2001 – Moving Lines achieved in 717 and 737

2001 – Lean Manufacturing Assessment tool, Fred Mitchell Award for Lean

2002 – Toyoda Boshoku trip, Lean activities with customer airlines, 757 moving line

2003 – Aircraft and Missiles merges with Space and Communications to form Integrated Defense Systems (IDS). John Van Gels implemented Lean Manufacturing Assessment at 26 IDS sites across the United States, into production systems that ranged from start-up to rate production.

2005 – St. Charles and Mesa facilities earn Shingo Prize for Excellence in Manufacturing

## RESULTS

Major improvements were made in Mesa, Arizona on the Apache helicopter program. The military needed the Apaches upgraded from whatever their current condition was, to a uniform newer configuration. The production problems with simultaneously building new helicopters, reworking existing used helicopters, and upgrading used vehicles, were huge. Yet with Lean, they reduced build hours 67%, cycle time 69%, and defects 90%.

The Joint Direct Attack Munition (JDAM) is a kit which integrates into conventional bombs to allow precision strike capability. The JDAM program in St. Charles, Missouri, implemented mixed model one-piece DFT® (Demand Flow® Technology) flow production. They increased the rate from 39 units per day to 146 units per day and achieved inventory turns unheard of in the industry, up from 3 to 78. DFT® was founded in 1984. It deals with increasingly impatient customers, who still expect high quality and low cost, but now demand products that once were thought to be absolutely unique and completely made-to-order. DFT® was another step that helped Boeing advance their Lean philosophy.

Boeing's St. Charles Weapons Enterprise Capability Center and Mesa Rotorcraft site – where the Apache helicopter is built – have been awarded the 2004-2005 Shingo Prize for Excellence in Manufacturing. This is the first time Boeing has won what Business Week has called the "Nobel Prize of manufacturing."

The Spokane, Washington plant did an excellent job of implementing Lean on their floor-panel manufacturing process. They reduced manufacturing time by 60% and floor space by more than 50%. The excess capacity allowed them to contract with Delta and Alaska Airlines to manufacture replacement floor panels for their planes. This made Spokane competitive in their niche and therefore attractive for another manufacturer to buy. Boeing is moving out of fabrication, concentrating on large-scale system integration.

In the Commercial Airplanes parts plants, employees reduced inventory levels by \$1 billion in 1999.

The 737 program is now giving tours of their moving line to employees from all over the country, suppliers, and customers. Since late 1999, just before Lean implementation began, to the end of 2004, they reduced factory cycle time 46%, stores inventory 59%, work-in-progress inventory 55%, and factory footprint 21%. Five years ago, flow time in Final Assembly was 22 days. It is now 11 days, with a goal of 8 days.

## LESSONS FROM THE ROAD

These lessons are some of those Boeing has learned while on the road to a Lean Enterprise.

- Success at Lean is largely due to the personalities of the leaders. Zealots put themselves at risk professionally
- Leaders that will engage in Lean themselves must be positioned in the right places
- Even if you think you have institutionalized something, if leadership backs off its support, the workforce backs off
- Lean is the best employee engagement tool Boeing has found
- Measuring activity, such as the number of AIWs completed, though not a measure of Lean's impact, does serve as a way to push people to learn and do Lean
- Make point improvements, then they can be connected into flow improvements. Flow improvements can be connected into system improvements
- External eyes are necessary, which is why consultants are utilized
- Internal and external pressures are essential

## CONCLUSION

The Lean journey at Boeing has been an increasing curve, with a continuous increase in understanding of the tools and philosophies. The slope has gotten steeper as the journey continues. Boeing built on Continuous Quality Improvement principles, started Lean with "popcorning" Accelerated Improvement Workshops (AIWs) throughout the company in 1990, faltered in Commercial Airplanes during the bad economic times of 1992, then regained momentum in the mid-1990s. The perception that World Class Competitiveness, 5S, AIWs, Six Sigma, and so on, are "flavors of the month", is giving way to

the realization that they are all part of the Boeing Production System. Boeing has developed a locomotive called the Lean Enterprise to which they add railroad cars as they learn more.

## **ACKNOWLEDGMENTS**

Many people contributed to Boeing's Lean journey over the years. I apologize for omitting those that should have been mentioned. I would not have been able to write this history without the information and materials freely provided by Dan Becker, John Black, Ross Bogue, Elizabeth Girdler, Craig Habakangas, Mike Herscher, Larry Loftis, Dennis Racey, Jan Martinson, and Bill Vogt. Thank you to Leslie Garrison for editing the rough drafts. Any errors or omissions are mine.

## **REFERENCES**

Black, John R. 1998. *A World Class Production System*, Crisp Management Library  
Dec 2004/Jan 2005. High Speed Performance, In *Boeing Frontiers Magazine*, vol 3, issue 8 available online at [http://www.boeing.com/news/frontiers/archive/2004/december/i\\_cal.html](http://www.boeing.com/news/frontiers/archive/2004/december/i_cal.html)  
A Historical Perspective, Moving Final Assembly Line Production and Implementing Lean Practices, available online at [http://www.boeing.com/commercial/initiatives/lean/lean\\_summary.html](http://www.boeing.com/commercial/initiatives/lean/lean_summary.html)