Acquisition Research Program:
Creating Synergy for Informed Change

Lean Six Sigma for Reduce Life Cycle Costs and Improved Readiness

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Outline

- Why implement Lean Six Sigma?
- Background on "What is Lean Six Sigma?"
  - Theory of Constraints
  - Lean Production
  - Six Sigma (Why 6, not 7 or 8?)
- A case study at NASWI and lessons
- How to implement Lean Six Sigma for military applications – Managerial guidelines

Why Lean Six Sigma

- During the life cycle of a weapon system a significantly larger amount of money gets spent on operating and maintaining the system than for acquiring it
- Efficient and effective logistics systems are therefore critically important for containing the operation and maintenance costs and for maintaining the highest level of military readiness
- Lean Six Sigma is strategically important and it is a proven logistics initiative for reduced life cycle costs and improved readiness

NAVAIR AIR*Speed*

Readiness (Ao)

$$Ao = \frac{\text{uptime}}{\text{uptime + downtime}} = \frac{\text{MTBM}}{\text{MTBM + MDT}}$$

MTBM (Mean Time Between Maintenance)

MDT (Maintenance Down Time)

- Transportation + Repair cycle time + Logistics delay including Administration delay
- Repair cycle time is only a fraction of the total MDT

How to improve readiness, Ao?

- ↓ MDT (cycle time reduction: LEAN)
- ↑ MTBM (better reliability & maintainability: 6 SIGMA)

Impact of Maintenance Down Time on Readiness and Cost: A Hypothetical Example

Assume that the Navy has 800 F/A-18 Hornet aircraft, each of which costs $50 million. The Standard Depot Level Maintenance (SDLM) must be done every 4 year. Because of the aging of aircraft and other reasons, the maintenance down time is currently one year.

Readiness = 4/(4+1) = 0.8

Thus, only 80% of 800, or 640 aircraft will be mission capable (MC) on average

A Hypothetical Example (Continued)

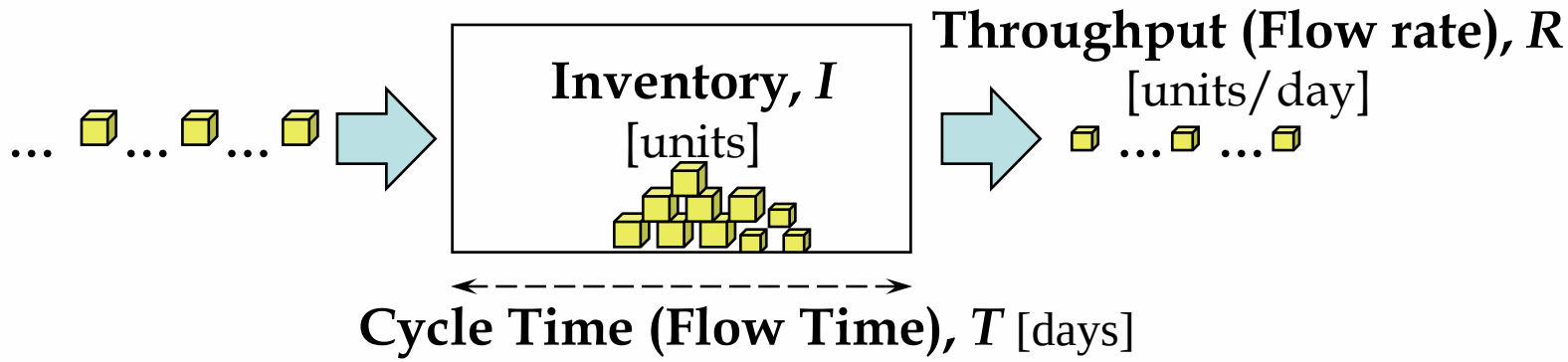
Assume further that by implementing Lean Six Sigma, MDT can be reduced to 6 months.

Readiness = 4/(4+0.5) = 0.889

Assuming that the adequate end-strength is 640 mission capable aircraft, a fleet size would be 640/0.889 = 720 aircraft.

Thus, the fleet size is reduced by 80 (800 – 720) aircraft freeing up $4 billion expenditure for other purposes.

Little's Law



Inventory = Throughput x Cycle Time

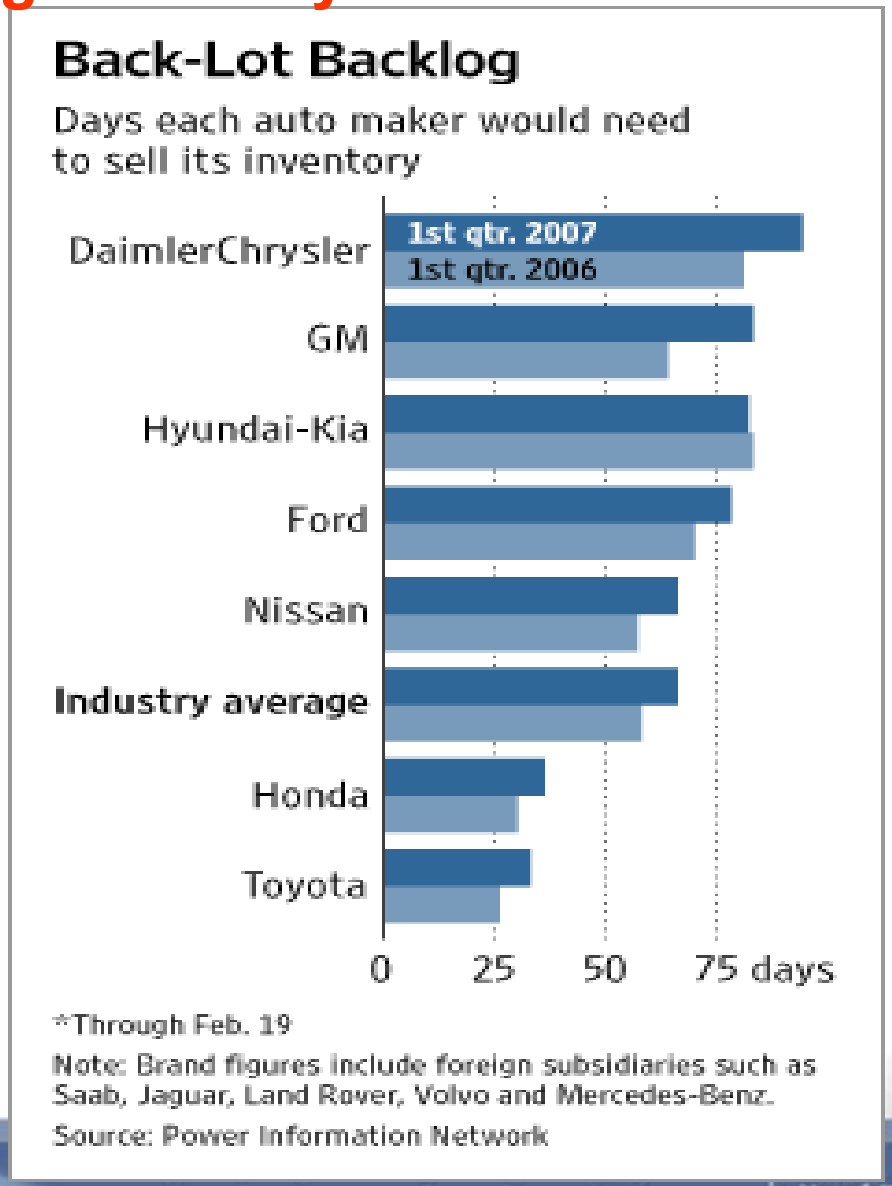
$I = R \times T$

What is new in this formula?

- Little, J.D. (1961), On the proof of a queueing formula L = λ W, *Operations Research*.

Source: MBPF

What's Wrong with Chrysler?



Wall Street Journal, 02 March 2007)

What's Wrong with Chrysler?

(Source: *Wall Street Journal*, 02 March 2007)

How much financial advantage does Toyota have over DaimlerChrysler from faster inventory turnover? Use back-lot backlog of 80 days for DaimlerChrysler, and 30 days for Toyota. Assume that the annual revenue of each company is $200 billion and the annual inventory rate is 20%.

Last Mile Inventory using Little's Law

Inv (DC) = \$200B/360^{days}*80^{days} = \$44.4B

Inv (Toyota) = \$200B/360 * 30 = \$16.7B

Chrysler carries \$27.7B more inventory than Toyota in the *back-lot backlog.*

It is equivalent to \$5.54B/year at a 20% annual inventory rate.

What is Lean Six Sigma

- Process improvement has always been a universal goal
  - Reducing cost, increasing speed, and improving quality
- Several successful techniques emerged in the twentieth century
  - Theory of Constraints: Focus is on Capacity
  - Lean Production: Focus is on cost and speed
  - Six Sigma: Focus is on quality and variability

What is 6 σ?

LT Miller fires a smart missile to destroy a very long enemy bridge stretching north-south. That means we are only concerned with horizontal (east-west) miss-distance. The miss-distance from the center of the bridge follows a normal distribution with a mean, μ = 0 and a standard deviation, σ = 1 yard. If the missile lands within 6 yards from the center, the bridge will be destroyed. What is the probability of a miss?

Pr (X > 6) + Pr (X < -6), where X ~ N(0, 1)

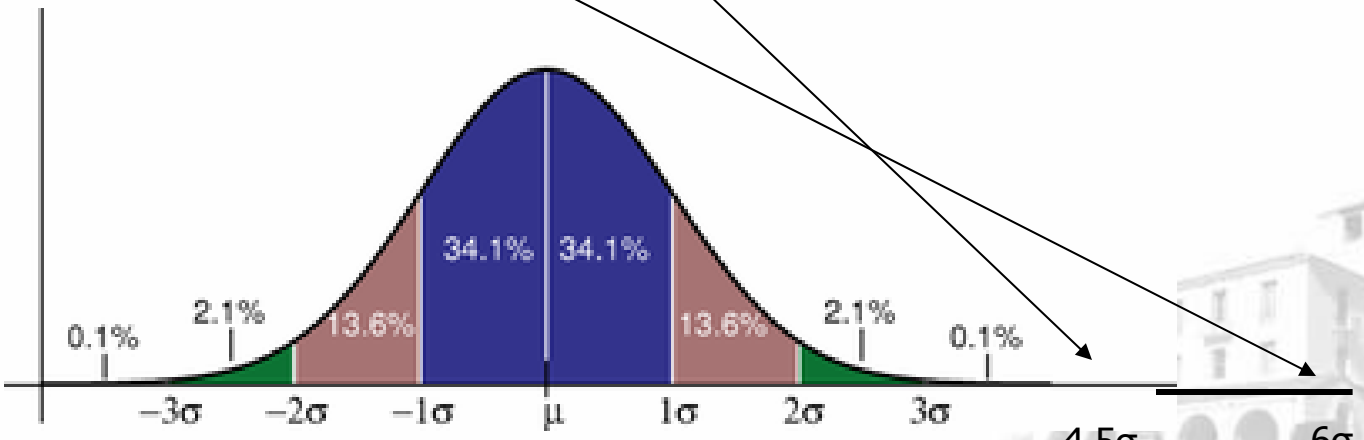
= [1 – NORMDIST (6, 0, 1, 1)] + NORMDIST (-6,0,1,1)

= 1 per billion rounds + 1 per billion rounds

= 2 per billion

6-sigma calculation using an EXCEL function

- Pr (X > μ + 4.5σ) = 1 – NORMDIST(4.5, 0, 1, 1) = 3.4 E-06 (or 3.4 per million)
- Pr (X > μ + 6σ) = 1 – NORMDIST(6, 0, 1, 1) = 9.9 E-10 (or 1 per billion)



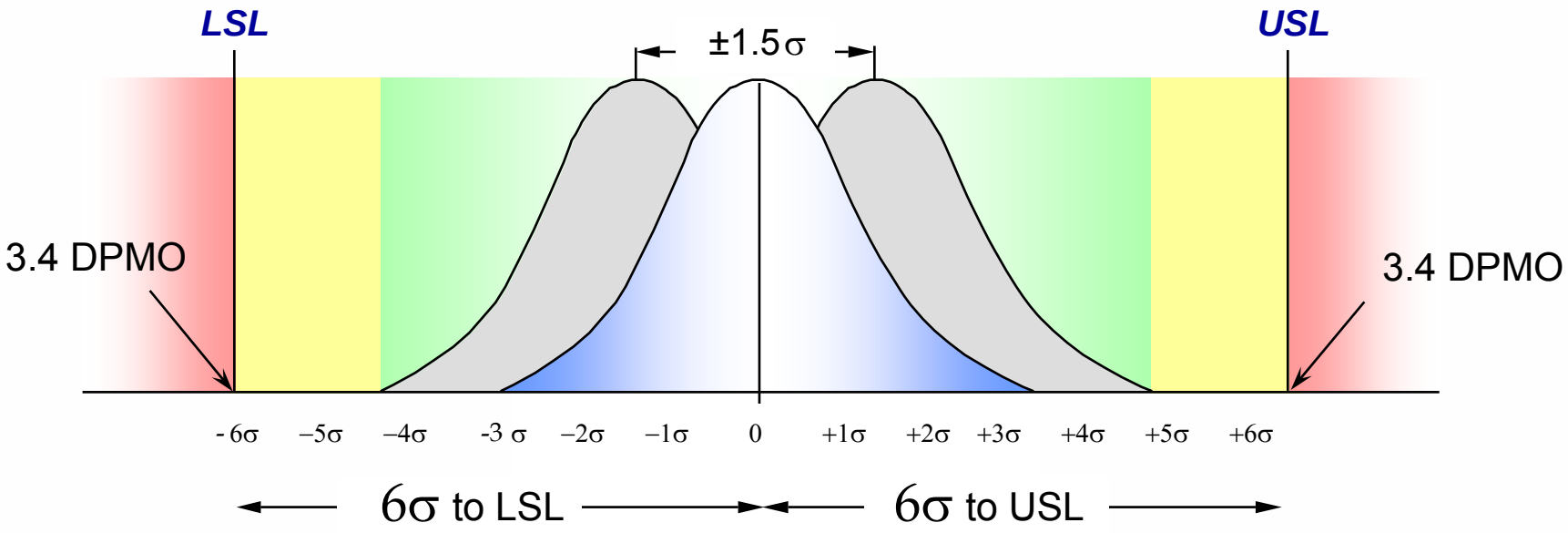
What is 6 σ? (continued)

LT Adams fires a missile to destroy a very long enemy bridge stretching north-south. That means we are only concerned with horizontal (east-west) miss-distance. The miss-distance from the center of the bridge follows a normal distribution with μ = 0 and σ = 1 . The aim-point error is estimated to be 1.5 yards. (He aims at the center of the bridge, but his gun actually aims at the point 1.5 yds from the center: calibration error) If the missile lands within 6 yards from the center, the bridge will be destroyed. What is the probability of a miss?

Pr (X > 4.5) + Pr (X < -7.5)
= [1 – NORMDIST (4.5, 0, 1, 1)] + NORMDIST (-7.5,0,1,1)
= 3.4 per million rounds + practically 0
= 3.4 per million rounds
(3.4 DPMO: defects per million opportunities)

Statistical Definition of Six Sigma

Statistical Definition



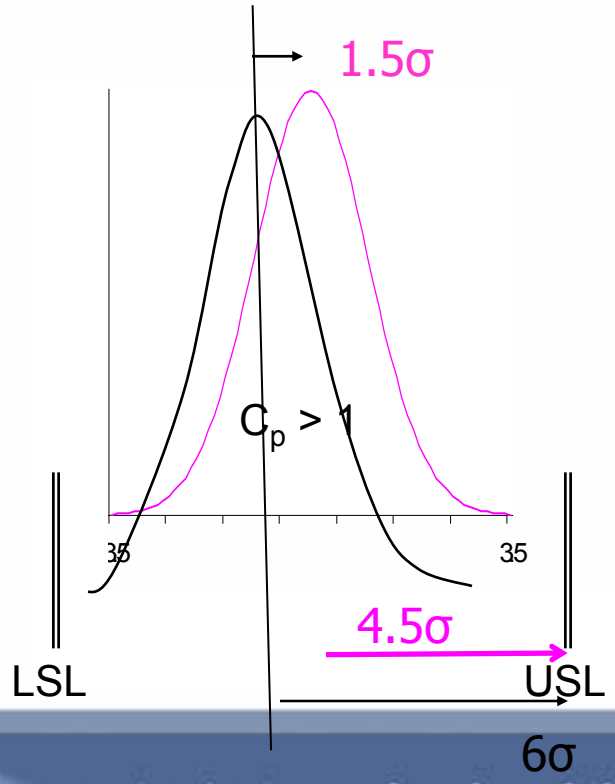
Six Sigma Definition

Prob (out of spec)

= Pr (X > 4.5) + Pr (X < -7.5)

=[1 – NORMDIST(4.5, 0, 1, 1)] + NORMDIST(-7.5,0,1)

= 3.4 E-06



1.5σ is the shift in the mean or the drift

3.4 per million fall to the right-hand-side of 4.5σ and practically 0 to the left-hand-side of -7.5σ

Importance of Variability

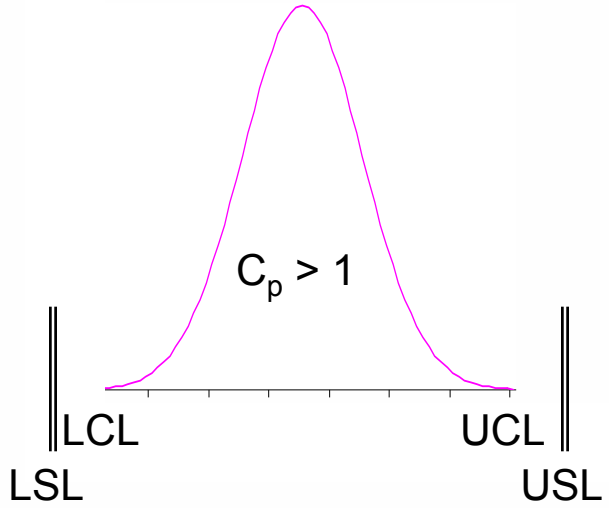
- Captain Weiser drops a bomb to destroy an enemy highway stretching north-south. The miss-distance of this bomb from the center of the highway follows a normal distribution with μ = 0 and σ = 2 . The aim-point error is estimated to be 1.5 yards. If the bomb lands within 6 yards from the center of the highway, the highway will be destroyed. What is the probability of a miss?

  Pr (X > 4.5) + Pr (X ≤ -7.5) where X ~ N (1, 2^2)
  = [1 – NORMDIST(4.5, 0, 2, 1)] + NORMDIST (-7.5,0,2,1)
  = 0.012 + 0.000088 = 0.012088, or

  1.2 misses per hundred (98.8% probability of hit)
  12,088 misses per million

Six Sigma Fundamentals

- Six Sigma has its origins in
  - Statistical Process Control
  - Total Quality Management
- DMAIC (define, measure, analyze, improve and control)
- Process capability (C_p): specification limits (LSL, USL) and control limits (LCL, UCL)



The Evolution of Six Sigma

- **Six Sigma 1.0 - Motorola: Tools focused on process quality**

  Six Sigma defined as a method to eliminate variation to customer requirements

  - Voice of Customer defines quality, a small subset of TQM quality
  - Define Measure Analyze Improve Control (DMAIC): data driven management
  - Concept of $Y = f(x_1, x_2, \ldots)$ to require management to be responsible for improving critical process inputs rather than just outputs (sales, profits, etc.)
  - Supported by a suite of TQM quality/statistical analysis tools
  - Variation is Evil, but also a source of information

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News—

* * *

World-Wide

■ **Petraeus reported little drop in Iraq violence, and Iran meddling.**

The general's assessment came as the Senate, 51-46, completed final passage of legislation setting a pullout timeline, which Bush declared "dead before arrival." Petraeus described an extremely "complex and challenging" security situation in which some areas improve while others deteriorate and said progress will be painful and halting. He also outlined "exceedingly unhelpful activities" by Iran. The day's violence in Iraq took 72 lives.

A U.S. officer was accused of letting prisoners use a cellphone in private and fraternizing with the daughter of one when he commanded Camp

DROPPED CALL

How Motorola Fell A Giant Step Behind

As It Milked Thin Phone, Rivals Sneaked Ahead On the Next Generation

By Christopher Rhoads And Li Yuan

A year ago, Motorola Inc. appeared headed for a third straight year of rich profits under Chief Executive Ed Zander, driven by its hit cellphone the Razr. "A lot of you are always asking what is after the Razr," Mr. Zander said in an April 2006 conference

Razr Burn

Motorola's daily share price. Edward Zander took over as CEO at the beginning of 2004.

Yesterday's close: $17.90

Source: WSJ Market Data Group

Unusua Offers a To Sha

All Harm Have Cha In KKR,

By Dennis K.

Amid growi vestors that pr buying public cheap so they at a hefty pro buyout players deal that offer of the action.

Yesterday, International to be acquire Roberts & Co Group Inc. for deal, which wo

The Evolution of Six Sigma

- **Six Sigma 2.0 - GE: Infrastructure of CPI (continuous process improvement) Success**

  TQM, Baldridge, ISO, Lean etc *Described* the future state, but not the actions to achieve it. Six Sigma *Prescribes* every action from present to future state.

  - Executive Leaders and process owners trained and actively engaged in the process
  - Projects selected specifically to execute leadership objectives
  - Defined organization, roles, and training levels (Black Belts, Directors, Sponsors, Green Belts, etc.) creates capability and accountability
  - Critical mass of resources defined (e.g.1% of employee population Black Belts)
  - Results are sustained by transferring training at all levels from consultant to client

3.4 DPMO must be interpreted carefully

- 3.4 DPMO was originally developed from Motorola for their electronic assembly line process control
- It assumes the process is “truly” normally distributed (Gaussian process).
- Are these acceptable?
  - 3.4 errors per million financial transactions at NYSE
  - 3.4 errors per million bits in telecommunication
  - 3.4 errors per million landings in FAA flight control computers
- What does “3.4 DPMO” mean in military?

Theory of Constraints

- *The Goal* by Eli Goldratt
- Theory of Constraints (TOC)
  - Identify the Constraint
  - Subordinate everything else
  - Use it in the best possible way
  - Eliminate the bottleneck
  - Go back to step one
  - Don't let inertia set in
- TOC leads to increased capacity and smoother flow of operations

Lean Production

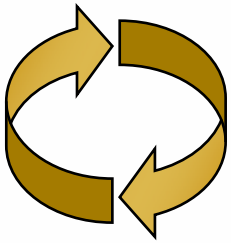
- Lean Production
  - has its origins in Frederic Taylor's *Principles of Scientific Management* (1911)
  - was implemented by Henry Ford in the production of Model T in early 1900's (31 hrs from iron ore to finished Model T, price fell from $850 in 1908 to $345 in 1916!)
  - was perfected by Toyota post WWII (multiple models/options, just-in-time system including rapid setups, Kanban pull, mistake-proofing, and almost zero inventory with maximum flexibility!)
- Lean Production, a term popularized by Womack, Jones and Roos (1991, *The Machine that Changed the World*) consists of:
  - Identify value stream
  - Remove waste
  - Make value flow
  - Pull value
  - Mistake-proof the process

Lean Production and Six Sigma are Complementary Techniques

Lean
Speed + ~~Waste~~ + Cost +
Implicit Infrastructure

Six Sigma
Quality + Cost +
Explicit Infrastructure

Lean Speed Enables Six Sigma Quality
(Faster Cycles of Experimentation/learning)



Six Sigma Quality Enables Lean Speed
(Fewer Defects Means Less Time Spent on Rework)

Synergistic merging of Lean Production and Six Sigma techniques has led to Lean Six Sigma

Navy LSS Implementations

- Aviation Intermediate Maintenance Division (AIMD), Whidbey Island reduced J-52 aircraft repair time from 468 hours to 233 hours
- Naval Air Warfare Center accounting practices resulted in annual saving of over $300K.
- Naval Aviation Systems Command's PMA offices reduced processing time from 240 days to 15 days.
- James F. Brice, director of the Naval Sea Systems Command's lean task force, says "lean and six sigma will help NAVSEA save $116 million this fiscal year (FY06)." [source: govexec.com, Nov 2, 2005]

Lean Implementation

AIRSpeed at J52 Engine Repair Shop

LCDR Eric Jafar, SC, USN
LCDR Terence Mejos, AMDO, USN
LT Chieh Yang, LDO, USN
(NPS Graduates, December 2006)

J52-P408 Engine for EA-6B Aircraft

- Manufacturer: Pratt & Whitney
- I-level Support Activities:
  - NASWI AIMD, WA
  - MALS 14, Cherry Point, NC
  - MALS 12, Iwakuni, Japan

http://www.is.northropgrumman.com

Lean Application

- Technical Focus: Value Stream Mapping (VSM)

  Step 1. Layout of current state
  Step 2. Analysis
  Step 3. Layout of future state
  Step 4. Implementation Plan
  Step 5. Implementation

- Human Focus: Employing Leadership Style
  - Creating a safe and engaging environment, and motivating people to constantly improve for the better.

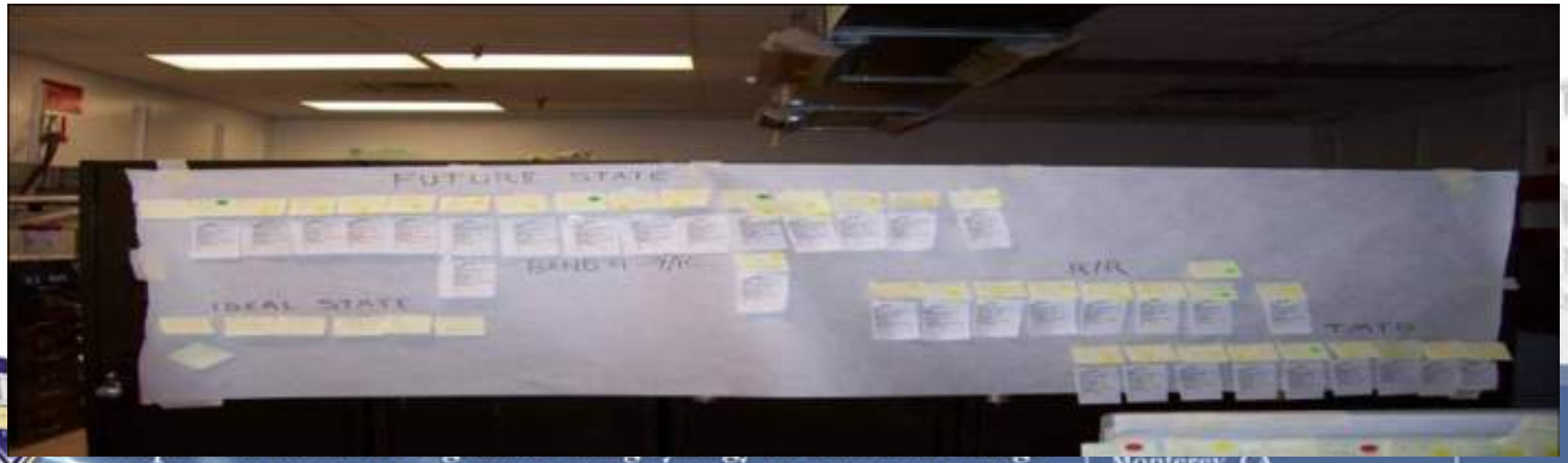
Analysis

- Seven+1 Wastes
  1. Overproduction
  2. Transportation
  3. Unnecessary Inventory
  4. Waiting
  5. Inappropriate Processing
  6. Defect
  7. Unnecessary Excess Motion
  8. Underutilization of Employees

VSM In-process

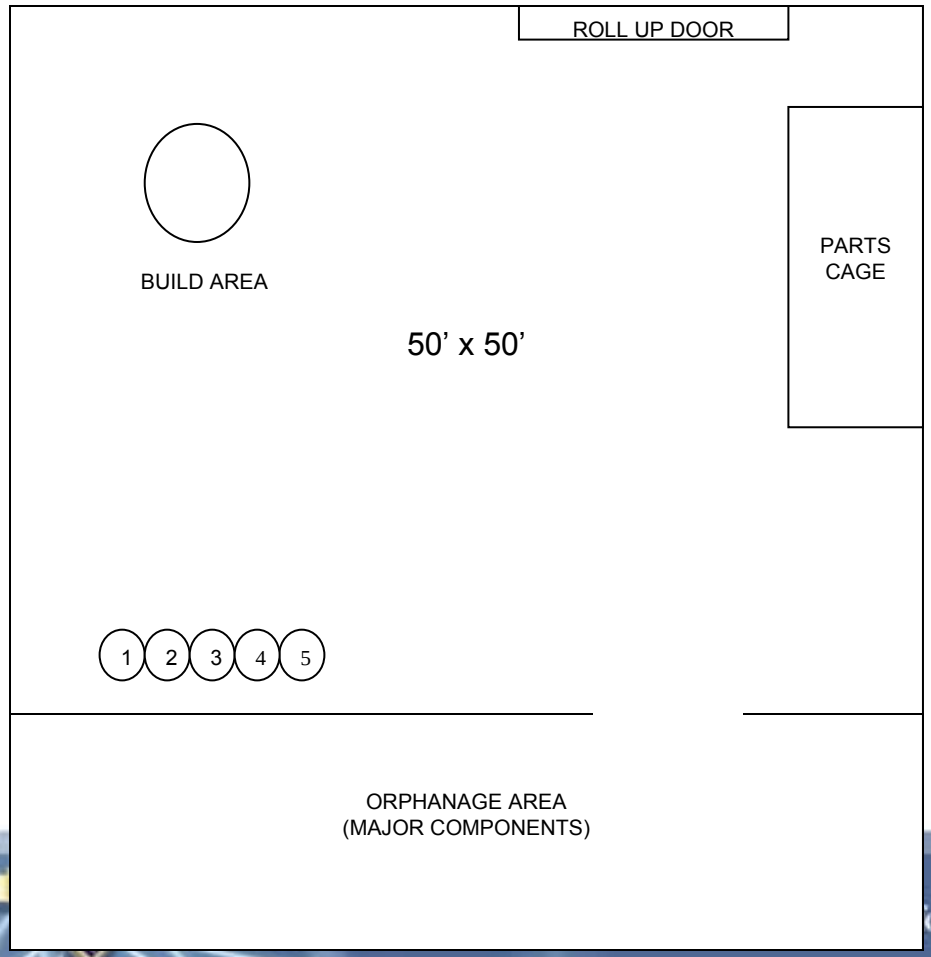
Current

Future

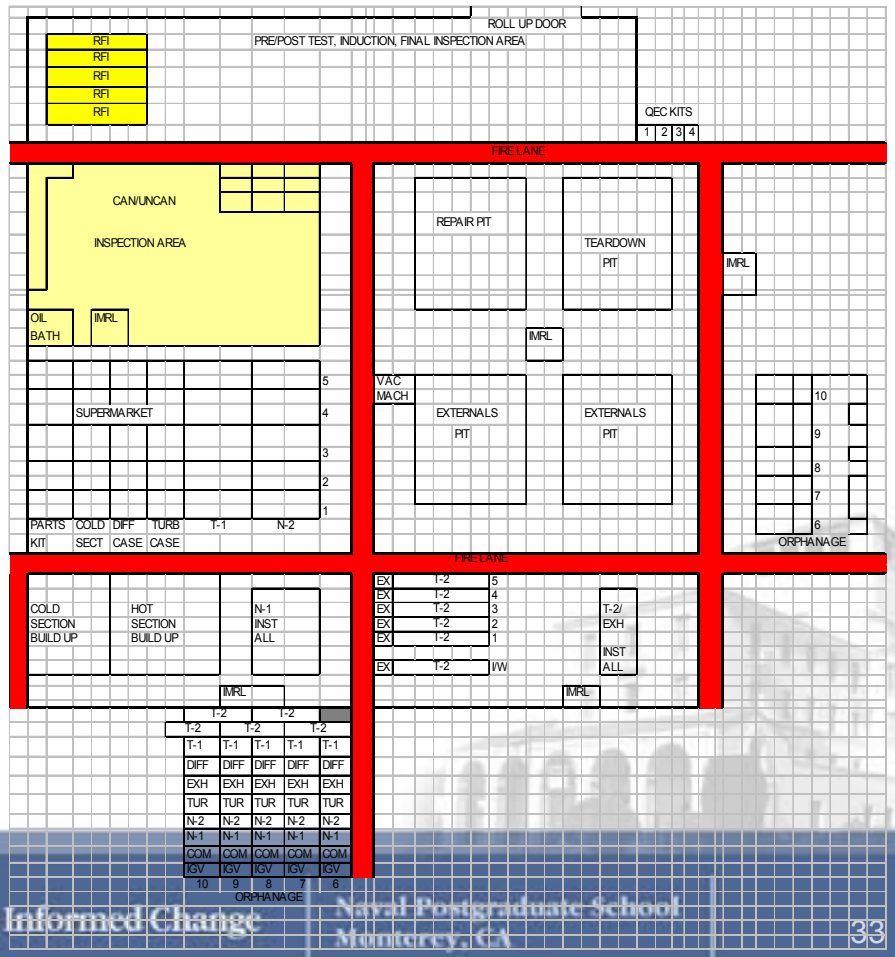


Comparison: Buildup Process

- Before: 2,240 ft



- After: 800 ft



Comparison: Orphanage

- Before

- After

Comparison: Supermarket

- Before

- After

Lean Operational Techniques

- Pull System
- Visual Control
- Mistake proofing (poka yoke)
- Equipment Changeover

Pull System

- Issuance of an RFI engine would “trigger” the process for building a replenishment engine, pulling parts from the Supermarket.

Visual Control

If a Pub is out of order it is immediately apparent.

Visual Control

Human Factors:
Cultural Transformation

Results

- Improved TAT
  - from 63 to 45 days
- Improved shop parts visibility/identification
- Reduced administrative burden/time
  - ordering parts
  - processing lost parts
  - swapping documents due to cannibalization
- Reduced spare parts/inventory
- More manageable cannibalization
- Working days reduced from 5/8 to 4/10, off on Friday.
- Improved morale…

Crisis/Sustainment Issues

- Oil Contamination
  - Increased sampling analysis standard
  - Shortened sampling interval
    - 7 “bare firewalls” in the Prowler Fleet
    - 30+ backlogged engines at NASWI
- New Division Officer/AIRSpeed Officer
  - Old norms begin to re-appear
- Working Hours
  - Back to 5/8

Other Sources of Problems

- Funding: Workload is determined by funding not by customers' needs.
- Culture: Taking Saturday off may not be acceptable to other commands in the same base
- Education on variability and risk management

Recommendations Based on Our Simulation Analyses

- Increase the RFI pool from 5 to at least 9
  - There are 111 EA6B aircraft with 140 spare engines. Current RFI pool has 5 engines. RFI pool should be increased to accommodate potential surge in demand.
  - The Navy already owns 140 spare engines. Increasing RFI pool is sunk cost.
- Change the quick fix station capacity from 1 to 4. (currently the quick fix station takes longer time. This is against the efficiency of the Shortest Processing Time (SPT) rule in scheduling.
- Understand and educate the concept of variability that is the very nature of military problems.

(Source: Department of the Navy, COMVAQWINGPAC, Power Plants Office)

Challenges of Implementing LSS in Military

- Success of LSS in the commercial sector
  - Severe competition
  - Incentives (symmetric reward/punishment)
  - Employee empowerment and participative management
- Military is traditionally organized and managed as a strict hierarchy.
- Frequent rotations and moves of officers

Challenges of Implementing LSS in Military

- Incentive systems
  - Huge (potential) cost savings (avoidance) from LSS projects within DoD have been reported. The boss may have hard times explaining "What is for me?"
  - Your savings could potentially subsidize someone else's poor performance.
- In the military the employees may enthusiastically embrace LSS initially, but it is difficult to maintain that enthusiasm in the long run w/o proper incentive systems.
- Since monetary incentives are difficulty to implement in the military, career enhancement or better promotion opportunities must be investigated.

Challenges of Implementing LSS in Military

- LSS methodologies were originally designed for manufacturing assembly systems where the demands are known or predetermined.
- As you move closer to a *foxhole* from a *factory*, the overall magnitude of uncertainty in demand and supply increases significantly. (It is also true in the commercial sector: remember the DaimlerChrysler example?)
- Military planners must selectively implement LSS in different parts of the military in different ways.

Challenges of Implementing LSS in Military

- Supply officers are encouraged to apply lean and JIT concepts to reduce inventory, but the system discourages them to implement lean/JIT (asymmetric reward system and risk aversion).
- "Lean" itself is not always desirable in military operations due to built-in variability. Yet the lean (removing wastes and non-value added activities) concepts help improve readiness and reduce cost.

Challenges of Implementing LSS in Military

- The benefits of reduced lifecycle costs and improved readiness from LSS implantations are too great.

Implementation Guidelines

- Active support of senior leaders is a must for a successful implementation of Lean Six Sigma
  - The need for change must be clearly articulated.
  - Commit to the change—make it last through leadership turnover.
  - Change and accountability should be driven from the top.
  - Actions speak louder than words - participate in the effort.

Implementation Guidelines

- Initial successes are critically important in launching Lean Six Sigma
  - Carefully choose initial projects.
  - Assign high-potential employees to those projects.
  - Provide financial and personnel resources to ensure success.
  - Initial successes turn the skeptics into believers.

Implementation Guidelines

- Emphasize continuing education and training
  - Include Lean Six Sigma Training in Leadership Development Programs
  - Senior organization leaders must be trained and engaged in project selection and monitoring of results
  - Deploy 1% of workforce as full-time Black Belt plus Green Belts, Champions, etc.
  - Black Belts should be selected from "future leaders of the organization"
  - Create Master Black Belts to take over training at all levels

Implementation Guidelines

- Monitor the Lean Six Sigma projects
  - Assign concrete goals to project leaders and hold the accountable for project results.
  - Provide stable funding to ensure long-term success.
  - Demand validated return on investment; Keep score in public.
  - Promote a philosophy that it is OK to save a dollar and give it up—it's not your money.
  - Middle management is likely to provide the most resistance — actively manage their participation (increase the ratio between those that get it and those that don't).
- Comments: Experience from an LSS seminar

NPS Initiatives

- Green belt educational requirements certificates
- LSS applications to health care systems
  - 16% of US GDP is being spent on health care systems (while 3% of GDP on defense)
  - Health care is one of the least efficient sectors in the US economy