16.660 / 16.853 / ESD.62J Introduction to Lean Six Sigma Methods
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The Start of Your Lean Journey
Learning Objectives

At the end of this module, you will be able to:

• Explain the origins of lean and six sigma
• Explain the “5S” lean tool
• Define Lean, lean enterprise and stakeholders
• Recognize why lean six sigma principles are being implemented in aerospace.
• Express that lean is a “journey” not a “state”
Lean Arises From Japanese Auto Industry

### Selected Metrics for US & Japan Automobile Manufacturers

<table>
<thead>
<tr>
<th>Product Development (mid 1980s)</th>
<th>Japanese Producers</th>
<th>American Producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Engineering Hrs per New Car (millions)</td>
<td>1.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Avg. Development Time per New Car (months)</td>
<td>46.2</td>
<td>60.4</td>
</tr>
<tr>
<td>Employees in Project Team</td>
<td>485</td>
<td>903</td>
</tr>
<tr>
<td>Supplier Share of Engineering</td>
<td>51%</td>
<td>14%</td>
</tr>
<tr>
<td>Ratio of Delayed Projects</td>
<td>1 in 6</td>
<td>1 in 2</td>
</tr>
</tbody>
</table>

### Summary of Assembly Plant Characteristics for Volume Producers, 1989

<table>
<thead>
<tr>
<th></th>
<th>Japanese in Japan</th>
<th>American in N Am</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity (hrs/veh)</td>
<td>16.8</td>
<td>25.1</td>
</tr>
<tr>
<td>Quality (defects/100 veh)</td>
<td>60</td>
<td>82.3</td>
</tr>
<tr>
<td>Inventory (days for 8 sample parts)</td>
<td>0.2</td>
<td>2.9</td>
</tr>
<tr>
<td>Work Force on Teams</td>
<td>69.3%</td>
<td>17.3%</td>
</tr>
<tr>
<td>Suggestions per employee</td>
<td>61.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Number of Job Classifications</td>
<td>11.9</td>
<td>67.1</td>
</tr>
<tr>
<td>Training Hrs of New Production Workers</td>
<td>380.3</td>
<td>46.4</td>
</tr>
</tbody>
</table>

Trends have continued since this 1989 data reported in *The Machine That Changed The World*
Lean emerged from post-WWII Japanese automobile industry as a fundamentally more efficient system than mass production.

<table>
<thead>
<tr>
<th>Craft</th>
<th>Mass Production</th>
<th>Lean Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Task</td>
<td>Customer</td>
</tr>
<tr>
<td>Operation</td>
<td>Single items</td>
<td>Synchronized flow and pull</td>
</tr>
<tr>
<td>Overall Aim</td>
<td>Mastery of craft</td>
<td>Eliminate waste and add value</td>
</tr>
<tr>
<td>Quality</td>
<td>Integration (part of the craft)</td>
<td>Inspection (a second stage after production)</td>
</tr>
<tr>
<td>Business</td>
<td>Customization</td>
<td>Economies of scale and automation</td>
</tr>
<tr>
<td>Strategy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvement</td>
<td>Master-driven continuous</td>
<td>Expert-driven periodic improvement</td>
</tr>
<tr>
<td></td>
<td>improvement</td>
<td></td>
</tr>
</tbody>
</table>

Lean thinking is the dynamic, knowledge-driven, and customer-focused process through which all people in a defined enterprise continuously eliminate waste and create value.
Six Sigma was developed by Motorola in the 1980s to systematically improve quality by elimination of defects.

<table>
<thead>
<tr>
<th></th>
<th>Six Sigma</th>
<th>Lean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective</strong></td>
<td>Deliver value to customer</td>
<td>Deliver value to customer</td>
</tr>
<tr>
<td><strong>Theory</strong></td>
<td>Reduce variation</td>
<td>Remove waste</td>
</tr>
<tr>
<td><strong>Focus</strong></td>
<td>Problem focused</td>
<td>Flow focused</td>
</tr>
<tr>
<td><strong>Assumptions</strong></td>
<td>• A problem exists</td>
<td>• Waste removal will improve business performance</td>
</tr>
<tr>
<td></td>
<td>• Figures and numbers are valued</td>
<td>• Many small improvements are better than system analysis</td>
</tr>
<tr>
<td></td>
<td>• System output improves if variation in all processes inputs is reduced</td>
<td></td>
</tr>
</tbody>
</table>

Six Sigma is a *data driven philosophy and process* resulting in dramatic improvement in products/service quality and customer satisfaction.

Lean and Six Sigma

- Transformation initiatives are often based on elements of Lean and Six Sigma
  - Lean optimizes flow and strives to eliminate waste
  - Six Sigma stresses quality through the elimination of variation in all enterprise processes
- A unified framework called *Lean Six Sigma* has emerged
- Enterprises usually adopt their own name. Some examples:
  - Textron - *Textron Six Sigma*
  - Pratt & Whitney - *ACE*
  - Rockwell Collins - *Lean Electronics*
  - US Air Force - *AFSO21*
  - Boeing - *Lean+
  - Rockwell Collins - *Lean Electronics*

The LAI Lean Academy® curriculum focuses on the fundamental concepts which underpin these and other transformation initiatives.
Lean Six Sigma Concepts and Terminology You Will Learn

- Processes
- Value
- Value stream
- 7 types of waste
- 5 S
- Flow
- Cycle time
- Takt time
- Balanced work
- Single piece flow
- Standard work
- Kitting
- Pull System
- Kanban
- Visual control
- Mistake proofing
- Three elements of collaboration
- Andon
- VSM
- Lean supply chains
- IPTs
- A3 charts
- SPC
- Six Sigma
- DFSS
- Process quality
- Kaizen
- Product quality
- Enterprises
- Stakeholders
- Internal customers
- External customers
- Process maps
- Leadership and management
- Price vs cost
- DFMA
- IPPD
- Hybrid supply chain
- Key characteristics
- DPMO
- 5 whys
- DMAIC
- Cp vs. Cpk
- Histograms
- Scatter Diagram
- Pareto chart
- PICK charts
- Product lifecycle
- Value added time
- And more…..
5 S - A simple “lean tool”

Before

Sort
Straighten
Scrub
Standardize
Sustain

After

Courtesy of Gregory Harris. Used with permission.
5S Exercise - 1

• We will apply 5S to a workplace and measure the improvement in executing our job.

• During each 30 second shift, your job is to strike out the numbers 1 to 49 in order

• The first page of numbers represents our current workplace

• Ready… Set…
5S Exercise - 2

- The first “S” is Sort
  - We have removed numbers between 50 and 90 which are not needed

- Ready… Set…

- What sort of improvement does this yield?
5S Exercise - 3

- Sort
- Straighten
- Scrub
- Standardize
- Sustain

- The second “S” is *Straighten* or *Set in Order*
  - We have installed a rack system to help locate the numbers.
  - Numbers go from bottom to top, left to right

- Ready… Set…

- What sort of improvement does this yield?
5S Exercise - 4

- Sort
- Straighten
- Scrub
- Standardize
- Sustain

The third “S” is Scrub - it’s tough to scrub a piece of paper, so we’ll skip it this time.
The fourth “S” is **Standardize**

- We’ve created a system of ordering the numbers from lowest to highest from left to right and top to bottom
- We’ve put one number in each box to standardize
- Ready… Set…
- What sort of improvement does this yield?
The fifth “S” is Sustain

This is your challenge: Sustain your lean activities

Often the hardest to achieve
Aerospace - A Flagship Industry…

Enabling the global movements of people and goods

Enabling the global acquisition and dissemination of information and data

Advancing national security interests

Providing a source of inspiration by pushing the boundaries of exploration and innovation

Reference: Murman, et. al., Lean Enterprise Value, Palgrave 2002
Industry Innovation Linked to Product Evolution

An industry that “came of age” in the Cold War Era cannot survive with an obsolete business strategy

Cost-Price Relationship

The fundamental cost–price relationship has changed in the defense industry since the early 90s!

“cost plus” profit equals price

profit 15%

cost

price

price customer is willing to pay

profit

cost

customer-determined price

(industry must lower costs to achieve profit!)
Aerospace industry historically underperforms capital goods manufacturers: This situation is changing with lean implementation.
Aerospace Enterprises

- Aerospace products are produced and supported by Enterprises

- There are many types of enterprises, e.g.
  - Program Enterprises - JSF, B-787, GPS
  - Multi-program Enterprises - Raytheon, United Technologies, USN
  - National and International - The US Aerospace Enterprise, The European Aerospace Enterprise

- Enterprises can overlap, intersect and otherwise be connected.
What is an Enterprise?

“One or more organizations having related activities, unified operation, and a common business purpose”

Black’s Law Dictionary, 1999

“Business” can mean for profit or not-for-profit or governmental
What are the Boundaries of an Enterprise?

- The enterprise boundaries need to be identified: Definition is contextual
- **Core enterprise**: Entities tightly integrated through direct or partnering agreements.
- **Extended enterprise**: From customer’s customer to supplier’s supplier.
Who Are Enterprise Stakeholders?

“Any group or individual who can affect or is affected by the achievements of the organization’s objective”

Freeman, Strategic Management: A Stakeholder Perspective, Pittman, 1984
“Value - how various stakeholders find particular worth, utility, benefit, or reward in exchange for their respective contributions to the enterprise.”

Murman et al., Lean Enterprise Value, Palgrave, 2002
What is A Lean Enterprise?

“A lean enterprise is an integrated entity that efficiently creates value for its multiple stakeholders by employing lean principles and practices.”

Murman et al., *Lean Enterprise Value*, Palgrave, 2002
Lean applies to all enterprise processes that deliver value to the customer and revenue to the enterprise.

Lean also applies to enabling infrastructure and enterprise leadership processes required to deliver program value.
In 1992 US Air Force asked:

Can the concepts, principles, and practices of the Toyota Production System be applied to the military aircraft industry?

Today we can say: Yes…

...if Lean is focused on enterprise value creation

Applying lean thinking over a 4 year period, Lockheed Martin reduced the cycle time to build space launch vehicles from 48.5 months for the .4Mlb Atlas II to 18 months for the 1.2Mlb Atlas V.

18 months matches the lead time needed by satellite manufacturers.
**Requirements**

- 25% greater *payload*
- 3 times greater ordnance *bringback*
- 40% increase in unfueled *range*
- 5 times more *survivable*
- Designed for future *growth*
- Replace the A-6, F-14, F/A-18 A/B/C/D
- Reduced support costs
- Strike fighter for multi-mission effectiveness

**Program Execution**

- Development budget capped at $4.88B
- Completed on schedule - 8.5 years from “go-ahead” to IOC
- Program was never re-baselined
- *High correlation of program management practices and LAI’s Lean Enterprise Model*

*Highly capable across the full mission spectrum*

Adapted from 2000 slide provided by F/A-18E/F Program.
Lean Electronics: Our Operating Philosophy

Results In the Office:
- Reduced Publishing Cycle Time 72%
- 70% Work In-Process Reduction
- 38% Productivity Improvement
- 77% Manuals Inventory Reduction

Results In the Factory:
- 25% Improvement in Productivity
- 46% Reduction in Inventory
- Cycle Time Reductions of up to 75%

Source: Rockwell Collins.
Kanban - A Lean Tool

• Kan(card) + ban(signal)
• Visual cuing system to indicate material, parts, and/or information is/are authorized to move downstream
• Examples

Other Examples
• Empty parts bin with spaces for predetermined parts
• Marked open space on production floor
• Marked line on storage rack
• Empty inbox in engineering

A card signaling replenishments of material are needed.

Lean is a “Journey” Not a “State”

• It took close to 30 years for Toyota to develop all of the aspects of the Toyota Production System (TPS), including the lean thinking that goes with that system.

• Consider the Kanban
  • 1950s - First Kanban experiments
  • 1960s - Kanban introduced company-wide
  • 1970s - Kanban distributed across suppliers

• And Toyota continues to develop and perfect the TPS, and to share their knowledge with others


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How long do you think it might take your company to implement lean thinking across their enterprise, starting with the knowledge now available from Toyota and others?

- 20 years
- 10 years
- 5 years
- 1 year

Hold up the colored 3 x 5 card of your choice
WELCOME to The Start of Your Lean Journey!
Take Aways - Class Exercise

• Lean six sigma practices emerged from the Japanese auto and US electronics industries
• Lean thinking applies across the enterprise
• An enterprise has a core and extended boundary and many stakeholders.
• Lean is a “journey” not a “state”
• Lean thinking relates to your current activity

On a 3x5 card, list the stakeholders for your department or team.
You do not need to write your name on the card
Reading List


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