16.660 / 16.853 / ESD.62J Introduction to Lean Six Sigma Methods
January (IAP) 2008

The Start of Your Lean Journey

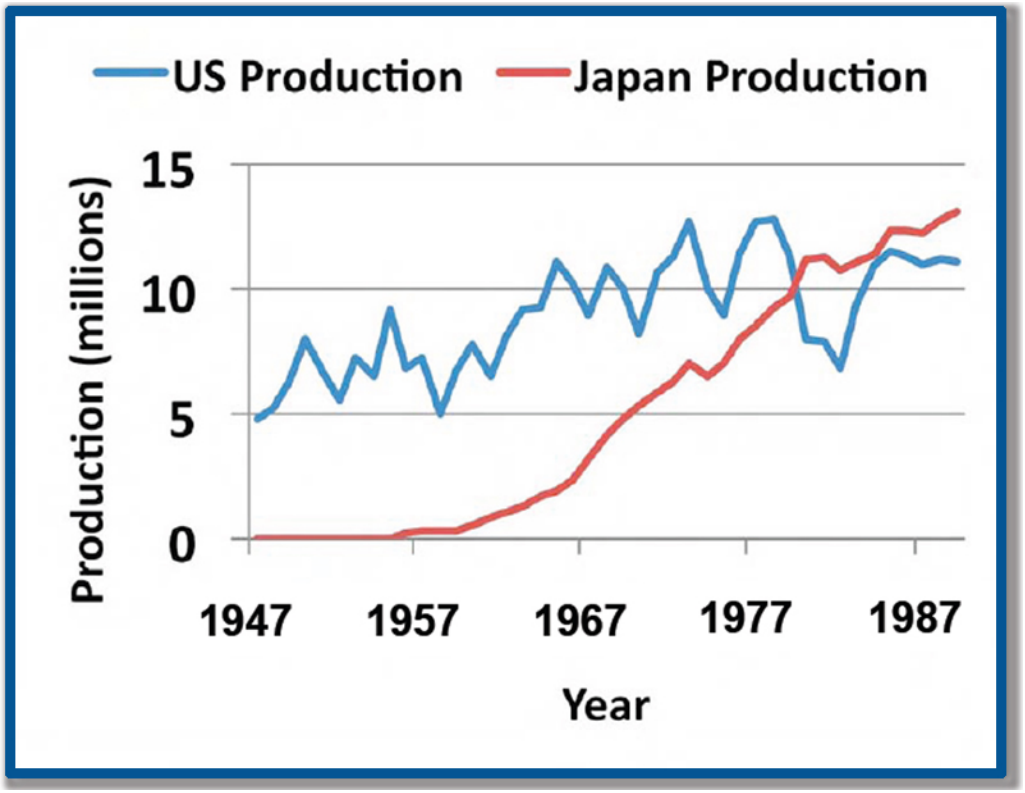
Learning Objectives

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		
Product Development (mid 1980s)		
	Japanese Producers	American Producers
Avg. Engineering Hrs per New Car (millions)	1.7	3.1
Avg. Development Time per New Car (months)	46.2	60.4
Employees in Project Team	485	903
Supplier Share of Engineering	51%	14%
Ratio of Delayed Projects	1 in 6	1 in 2
Summary of Assembly Plant Characteristics for Volume Producers, 1989		
	Japanese in Japan	American in N Am
Productivity (hrs/veh)	16.8	25.1
Quality (defects/100 veh)	60	82.3
Inventory (days for 8 sample parts)	0.2	2.9
Work Force on Teams	69.3%	17.3%
Suggestions per employee	61.6	0.4
Number of Job Classifications	11.9	67.1
Training Hrs of New Production Workers	380.3	46.4



Trends have continued since this 1989 data reported in *The Machine That Changed The World*

Lean Thinking Introduced

Lean **emerged from post-WWII Japanese automobile industry as a fundamentally more efficient system than *mass* production.**

	Craft	*Mass Production*	*Lean Thinking*
Focus	**Task**	**Product**	**Customer**
Operation	**Single items**	**Batch and queue**	**Synchronized flow and pull**
Overall Aim	**Mastery of craft**	**Reduce cost and increase efficiency**	**Eliminate waste and add value**
Quality	**Integration (part of the craft)**	**Inspection (a second stage after production)**	**Inclusion (built in by design and methods)**
Business Strategy	**Customization**	**Economies of scale and automation**	**Flexibility and adaptability**
Improvement	**Master-driven continuous improvement**	**Expert-driven periodic improvement**	**Worker-driven continuous improvement**

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.**

Adapted from Murman, et. al, *Lean Enterprise Value*,, Palgrave, 2002.

Comparison of Lean & Six Sigma

Six Sigma was developed by Motorola in the 1980s to systematically improve quality by elimination of defects.

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

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

Adapted from Nave, Dave. "How to Compare Six Sigma, Lean, and the Theory of Constraints." Quality Progress. March 2002

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+*

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”

- Sort
- Straighten
- Scrub
- Standardize
- Sustain

Before

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

- Sort
- Straighten
- Scrub
- Standardize
- Sustain

- 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**

5S Exercise - 5

- Sort
- Straighten
- Scrub
- **Standardize**
- Sustain

- 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?

5S Exercise - 5

- Sort
- Straighten
- Scrub
- Standardize
- **Sustain**

- **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

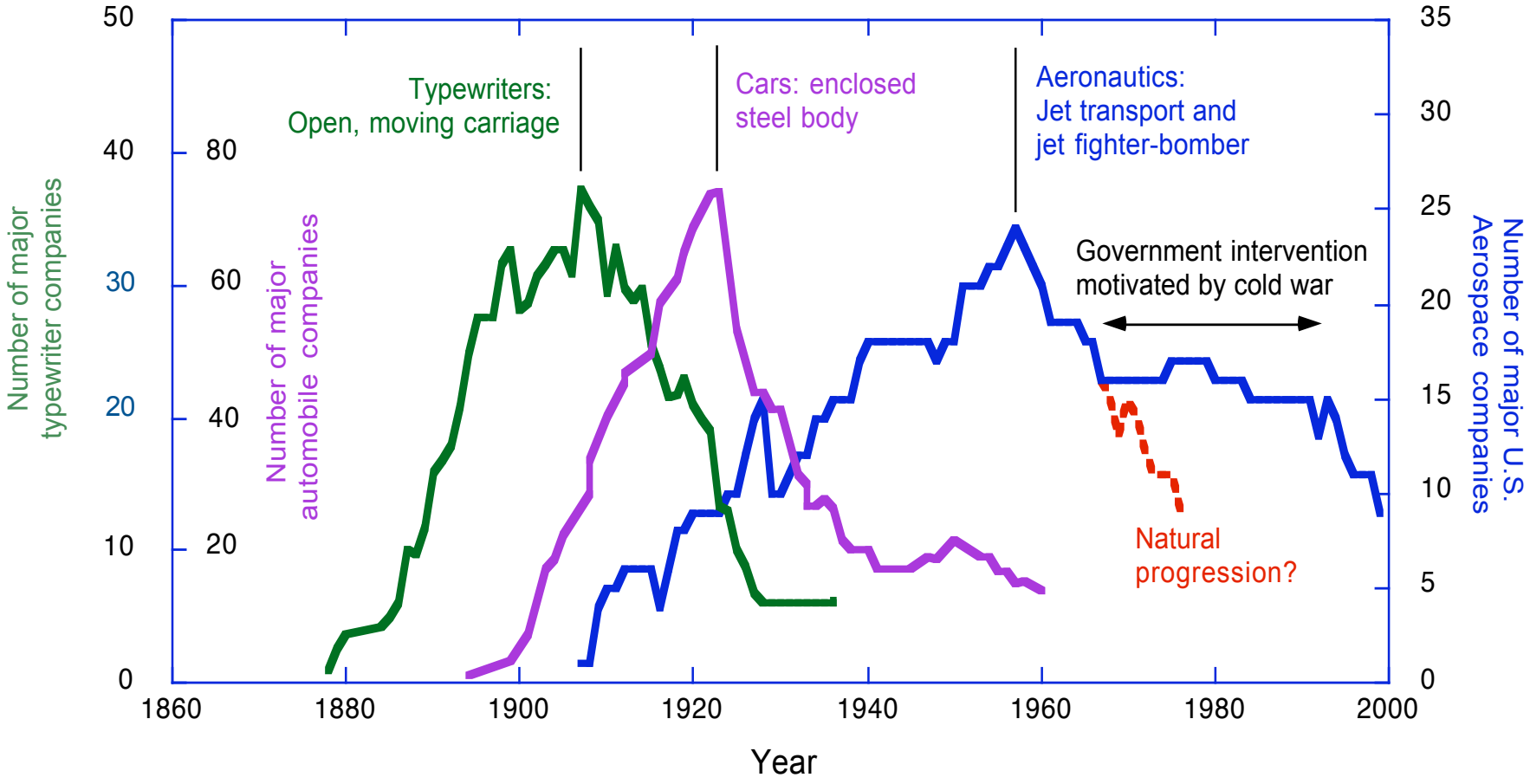
Enabling the global acquisition and dissemination of information and data

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

References: For typewriters, George Nichols Engler; for cars, Entry and Exit of Firms in the U.S. Auto Industry: 1894-1992, National Academy of Science; for aerospace, S. Weiss and A. Amir, "The Aerospace Industry", in Encyclopedia Britannica.

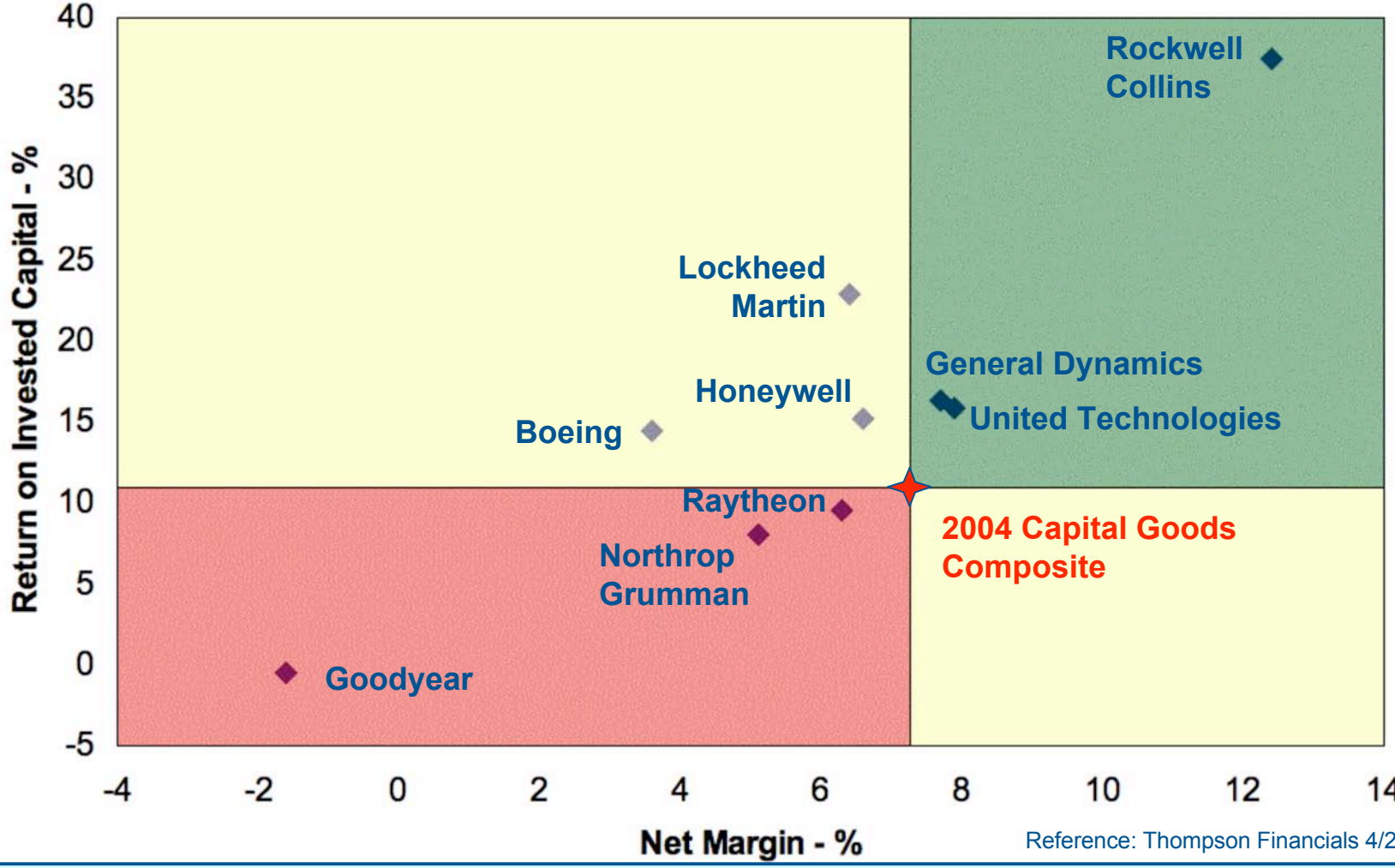
Cost-Price Relationship

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

"cost plus" profit equals price

customer-determined price (industry must lower costs to achieve profit!)

2006 Aerospace Industry Metrics



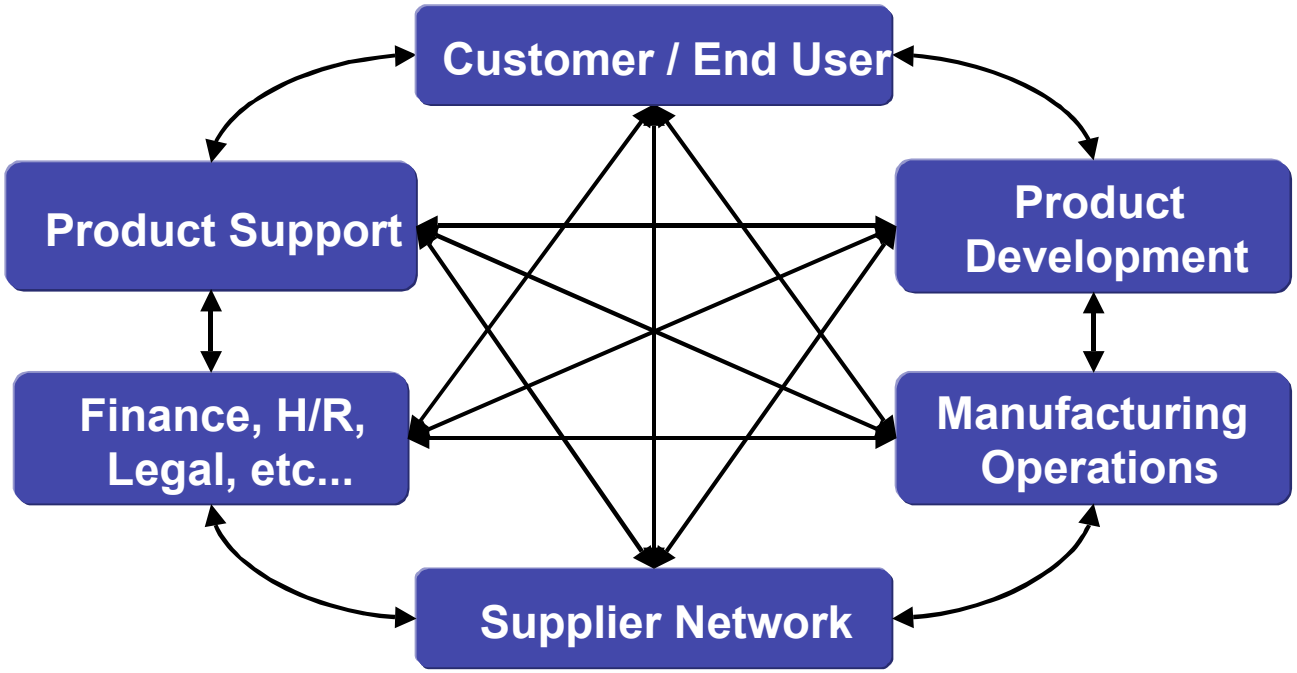
Reference: Thompson Financials 4/2007

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?



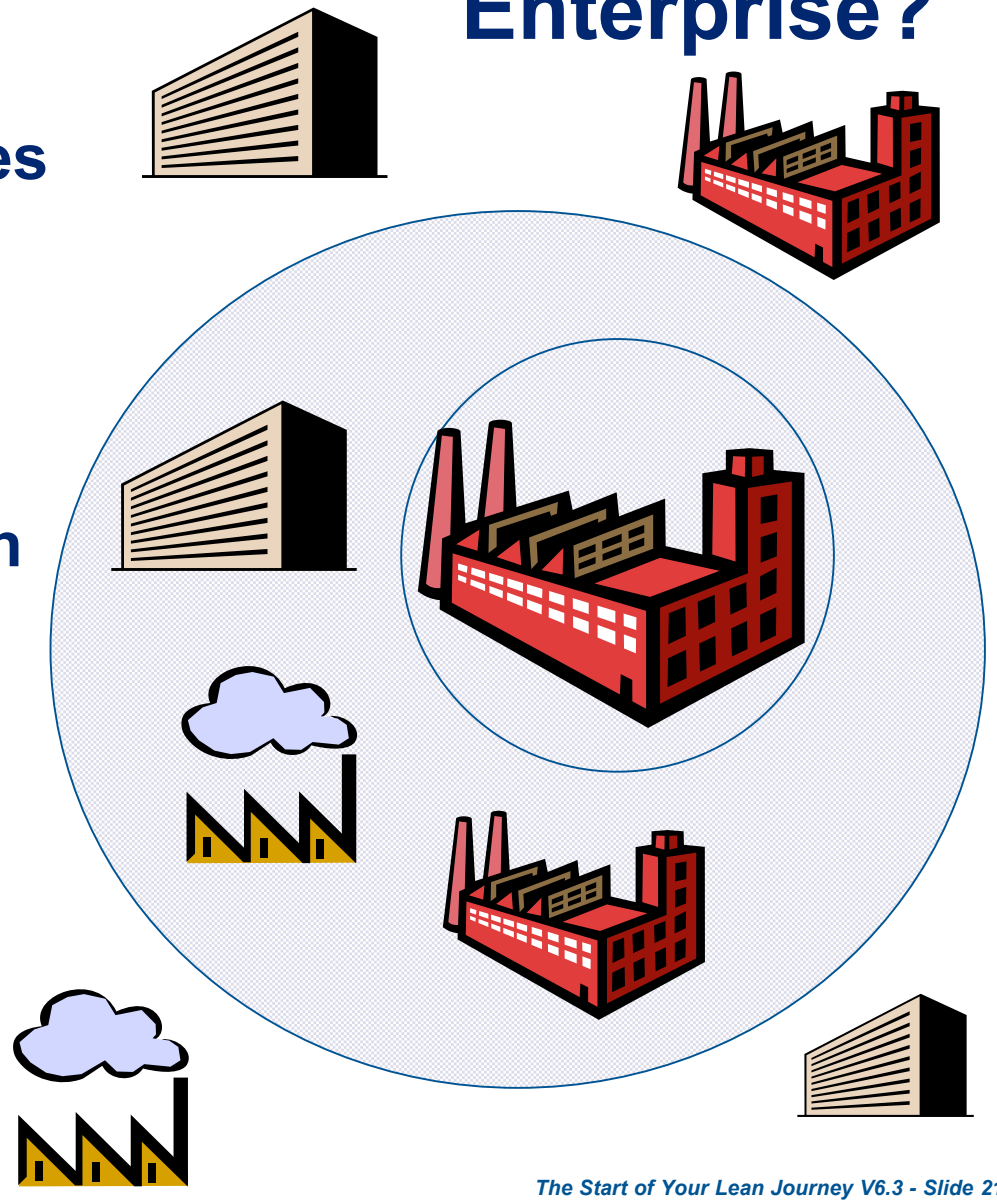
"One or more organizations having related activities, unified operation, and a common business purpose"

Black's Law Dictionary, 1999

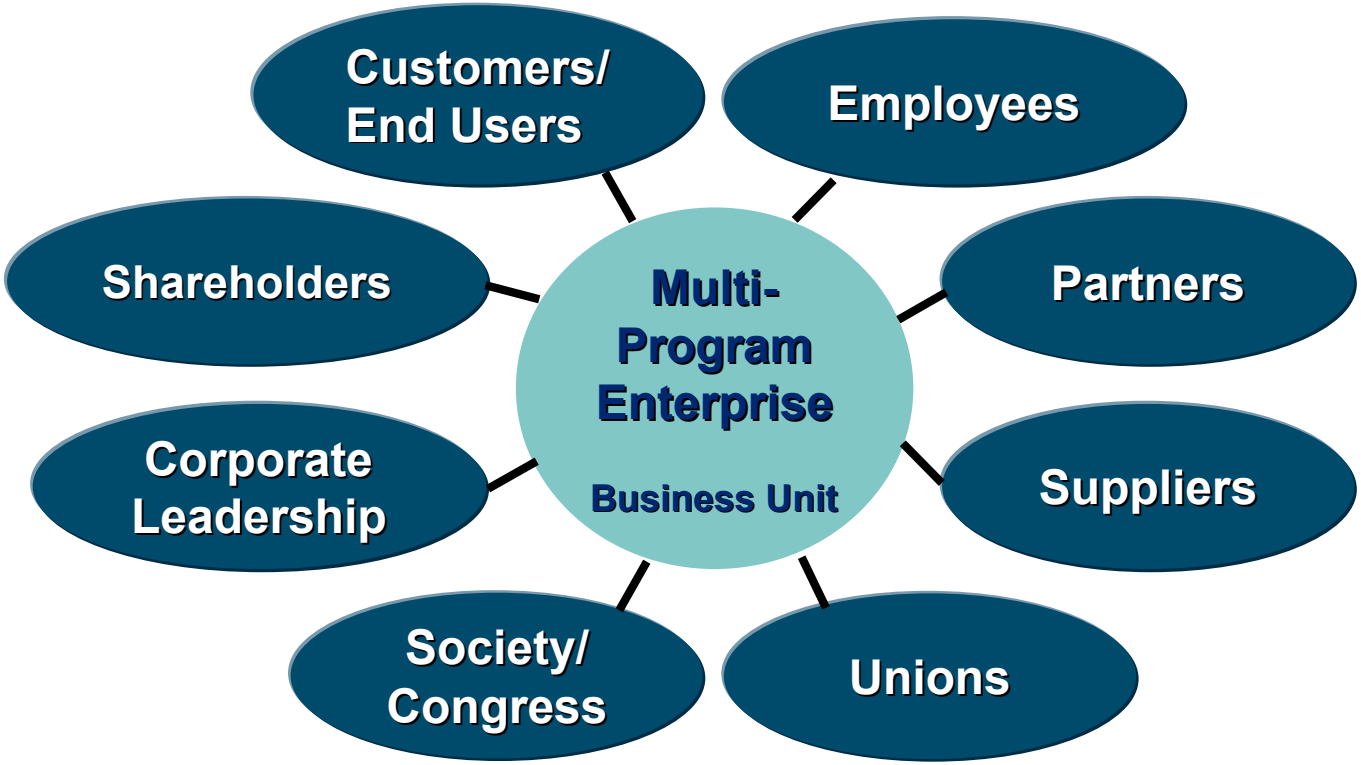
"Business" can mean for profit or not-for-profit or governmental

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"

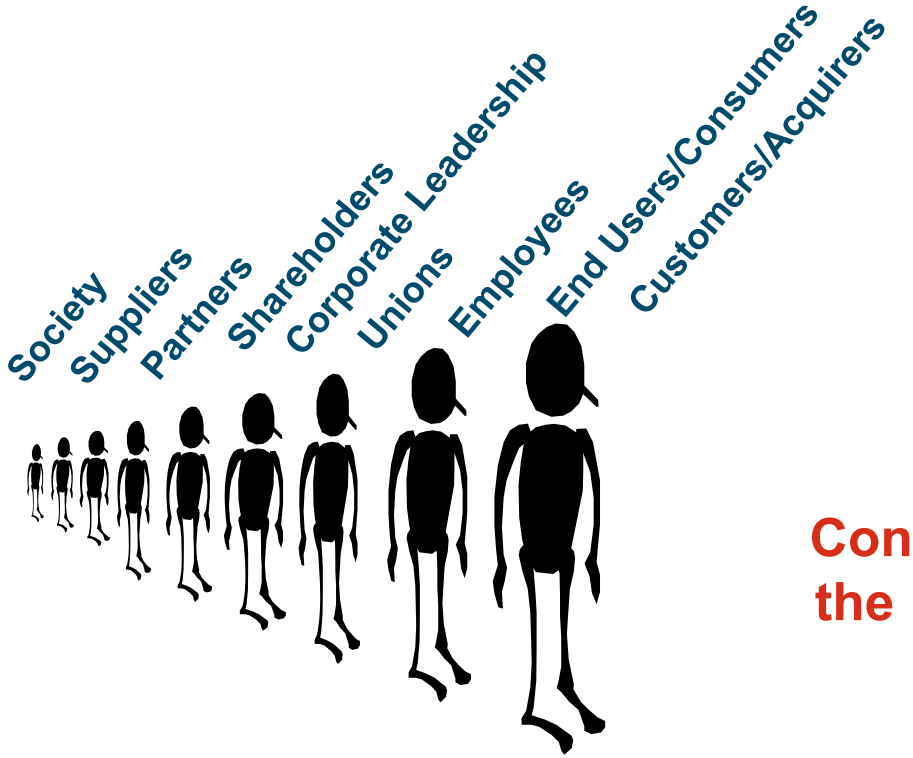
Freeman, *Strategic Management: A Stakeholder Perspective*, Pittman, 1984

Stakeholder Value

"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

Value Expected from the Enterprise

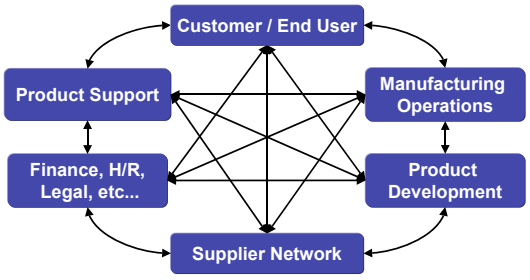


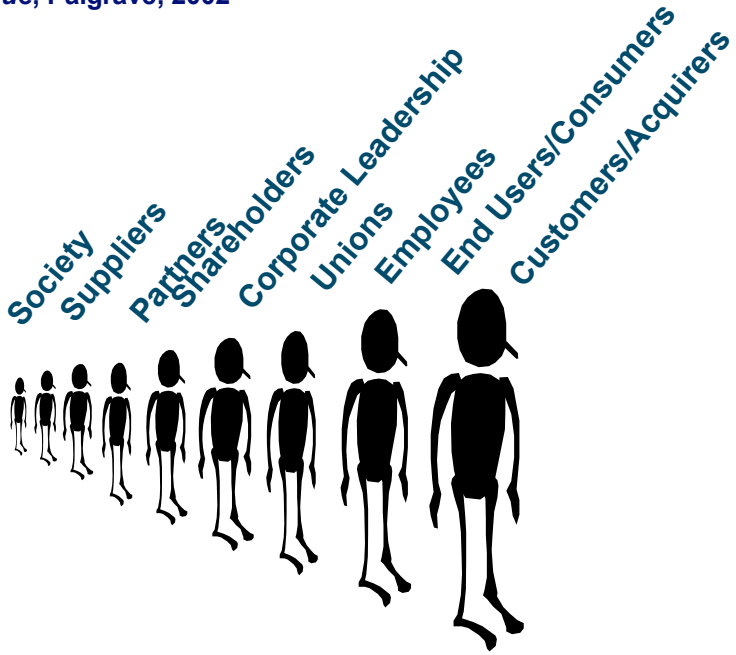
Value Contributed to the Enterprise

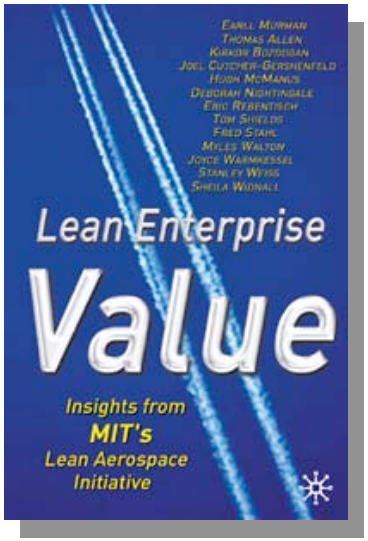
What is A Lean Enterprise?

"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

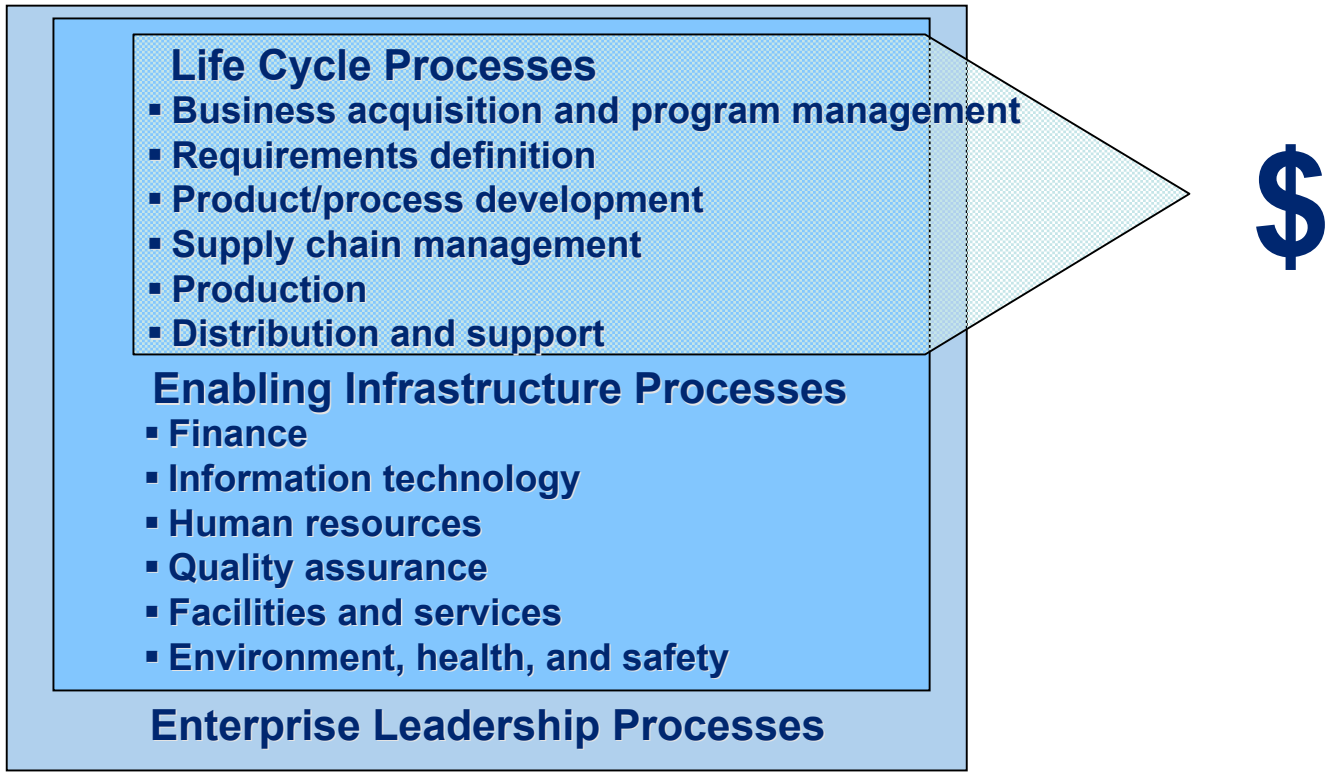






Courtesy of Earll Murman and Palgrave Macmillian, http://www.palgrave.com/.

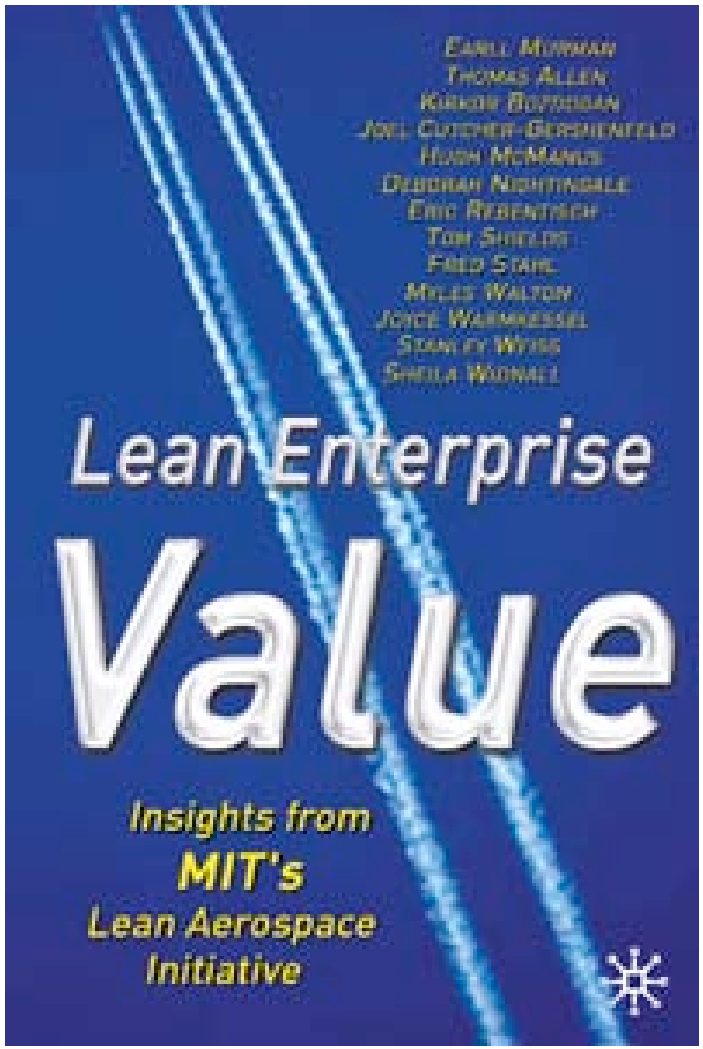
Lean Applies to All Enterprise Processes



Lean applies to production and all other life cycle 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

Lean Produces Results in Aerospace



Courtesy of Earll Murman and Palgrave Macmillian, http://www.palgrave.com/.

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

Atlas Program Cycle Time Reduction

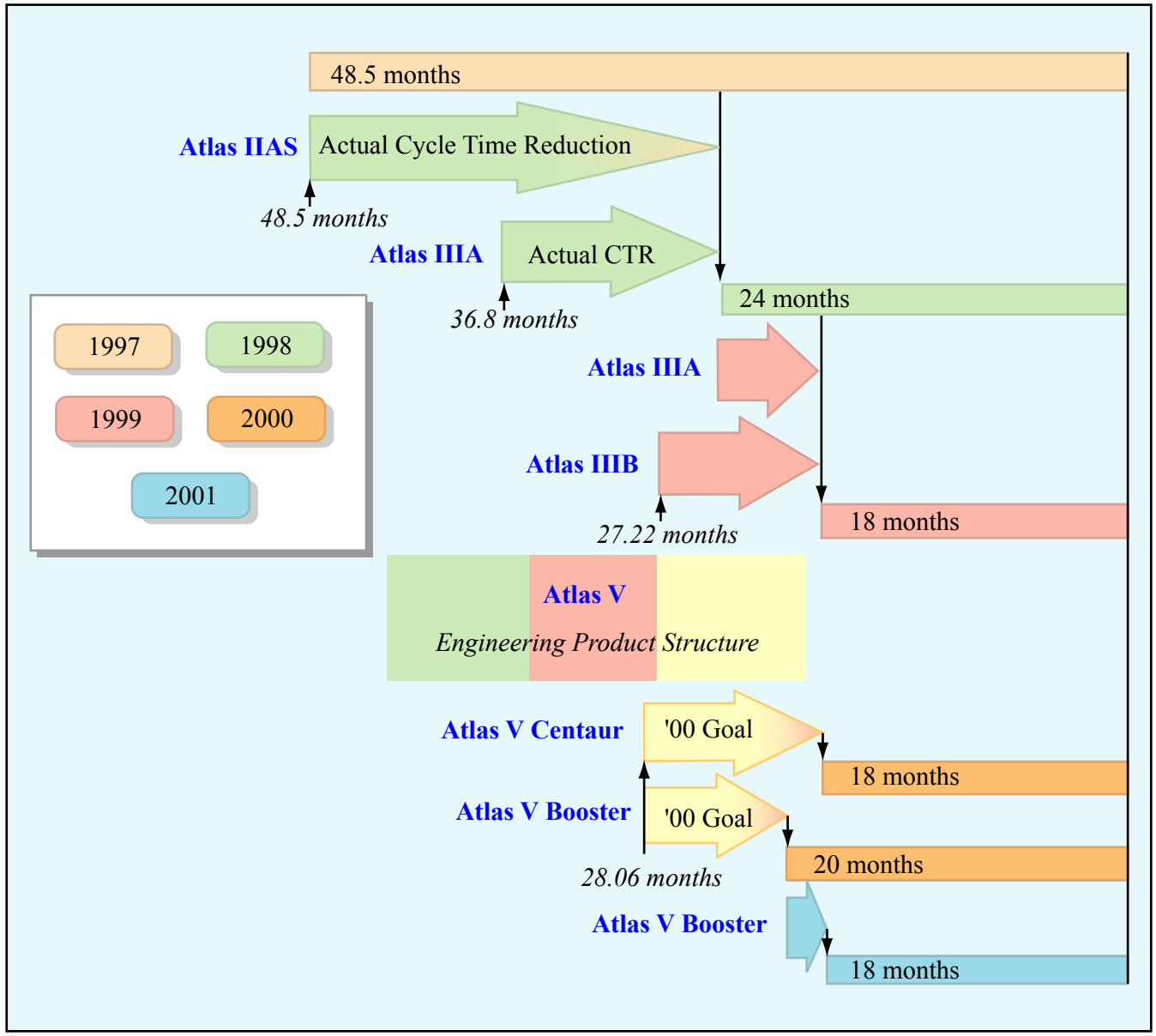


Figure by MIT OpenCourseWare.

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.

F/A-18E/F Super Hornet
"An Evolving Lean Enterprise"

Requirements

- 25% greater *payload*
- 3 times greater ordnance *bringback*
- 40% increase in unrefueled *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

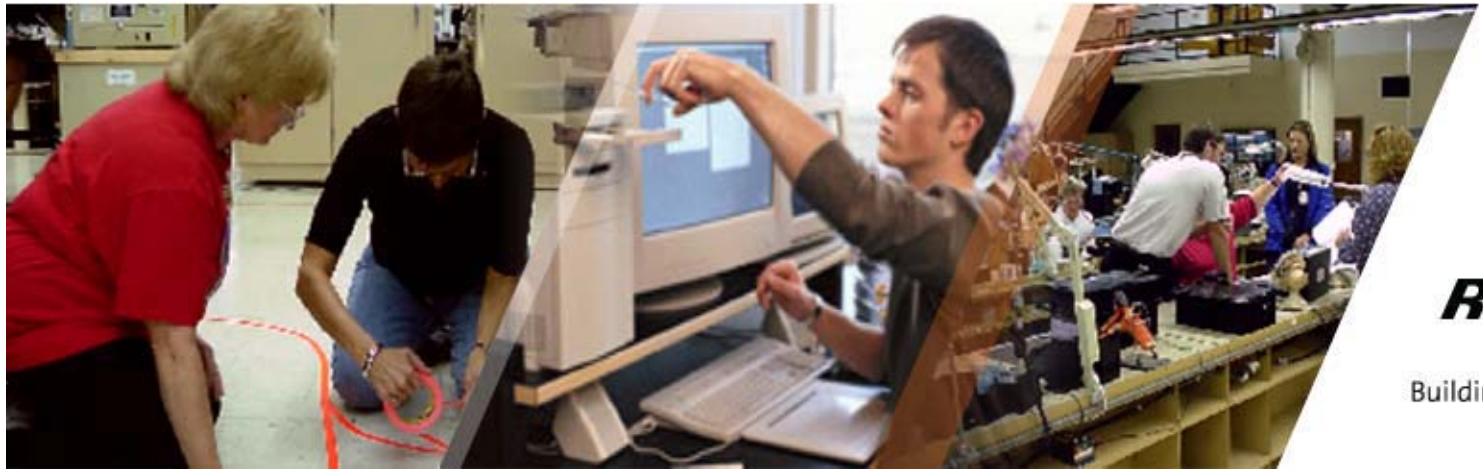
Program Execution

- 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



Rockwell Collins
Building trust every day

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%

Courtesy of Rockwell Collins. Used with permission

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

://www.glovia.com/pdf/datasheets/Kanban.pdf

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

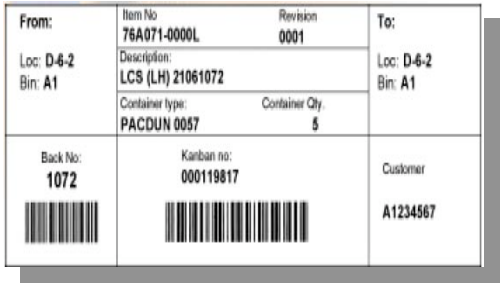
Courtesy of Glovia. Used with permission.

A card signaling replenishments of material are needed.

Adapted from: Hovav, M, Khattar, S, Katzen, J, "Kanban/Supply Chain Sequencing", Presentation to MIT ESD.60 Lean/Six Sigma Systems. Summer 2004

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



://www.glovia.com/pdf/datasheets/Kanban.pdf

Courtesy of Glovia.
Used with permission.

Adapted from: Hovav, M, Khattar, S, Katzen, J, "Kanban/Supply Chain Sequencing", Presentation to MIT ESD.60 Lean/Six Sigma Systems. Summer 2004

Question

How long do you think it might take your company to 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

Dertouzous, M.L., Lester, R.K. and Solow, R.M., *Made in America: Regaining The Productive Edge,* MIT Press, Cambridge 1989

Harry, M, and Schoeder, R., *Six Sigma*, Currency, New York, 2000

Liker, J. *The Toyota Way*, McGraw Hill, New York, 2004

Murman, E., Allen, T., Bozdogan, K., Cutcher-Gershenfeld, J., McManus, H., Nightingale, D., Rebentisch, E., Shields, T., Stahl, F., Walton, M., Warmkessel, J., Weiss, S., and Widnall, S., *Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative*, Palgrave, New York, 2002

Shingo, S., *A Study of the Toyota Production System*, Productivity Press, Portland, 1989

Womack, J, Jones, D. and Roos, D., *The Machine That Changed the World*, Rawson Associates, New York, 1990

Womack, J. and Jones, D., *Lean Thinking*, Simon & Shuster, New York, 1996

Acknowledgements

- Venkat Allada – University of Missouri, Rolla
- Ron Bengelink – ASU, Boeing retired
- Earll Murman – MIT
- Aaron Ravenscroft - Wabtec Corporation
- Steve Shade – Purdue
- Stan Weiss – Stanford University, Lockheed Martin Retired