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

LAI Lean Academy™

Lean Engineering Basics

2 Key Take Aways

1. Lean thinking applies to the engineering process

2. Engineering plays a critical role in creating value in a lean enterprise

Learning Objectives

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

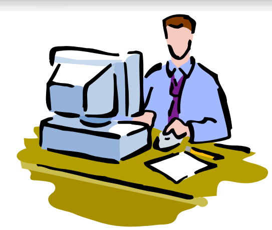
- Explain how lean principles and practices apply to engineering
- Explain why customer value and the "front end" of engineering are critical to product success
- Describe how lean engineering enables lean in the enterprise and throughout the product lifecycle
- Describe tools for lean engineering
- Apply lean engineering techniques to redesign a simulated airplane

Applying Lean Fundamentals to Engineering

Lean Thinking Steps	Manufacturing	Engineering
Value	Visible at each step Goal is defined	Harder to see Goal is emergent
Value Stream	Parts and materials flows	Information and knowledge flows
Flow	Iterations are waste	Planned iterations OK Must be efficient
Pull	Driven by takt time	Driven by enterprise needs
Perfection	Process repeatable without errors	Process enables enterprise improvement

Source: McManus, H.L. "Product Development Value Stream Mapping Manual", LAI, April 2004

***Information** flows in the Engineering Value Stream*

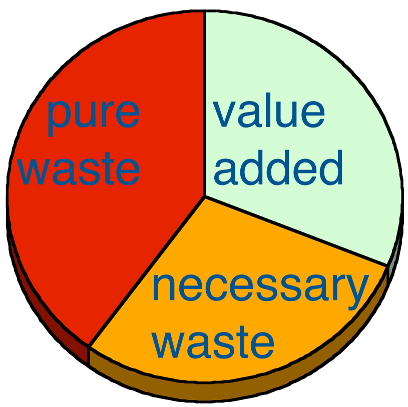


Seven Wastes Revisited

1. Over-production	Creating too much material or information
2. Inventory	Having more material or information than you need
3. Transportation	Moving material or information
4. Unnecessary Movement	Moving people to access or process material or information
5. Waiting	Waiting for material or information, or material or information waiting to be processed
6. Defective Outputs	Errors or mistakes causing the effort to be redone to correct the problem
7. Over-processing	Processing more than necessary to produce the desired output

Using Efficient Engineering Processes:

Applying lean thinking to eliminate wastes and improve cycle time and quality in engineering



- **Effort is wasted**
  - **40% of PD effort "pure waste", 29% "necessary waste"** *(workshop opinion survey)*
  - **30% of PD charged time "setup and waiting"** *(aero and auto industry survey)*

- ***Time* is wasted**
  - **62% of *tasks* idle at any given time** *(detailed member company study)*
  - **50-90% task idle time found in Kaizen-type events**

Source: McManus, H.L. "Product Development Value Stream Mapping Manual", V1.0, LAI, Sep 2005

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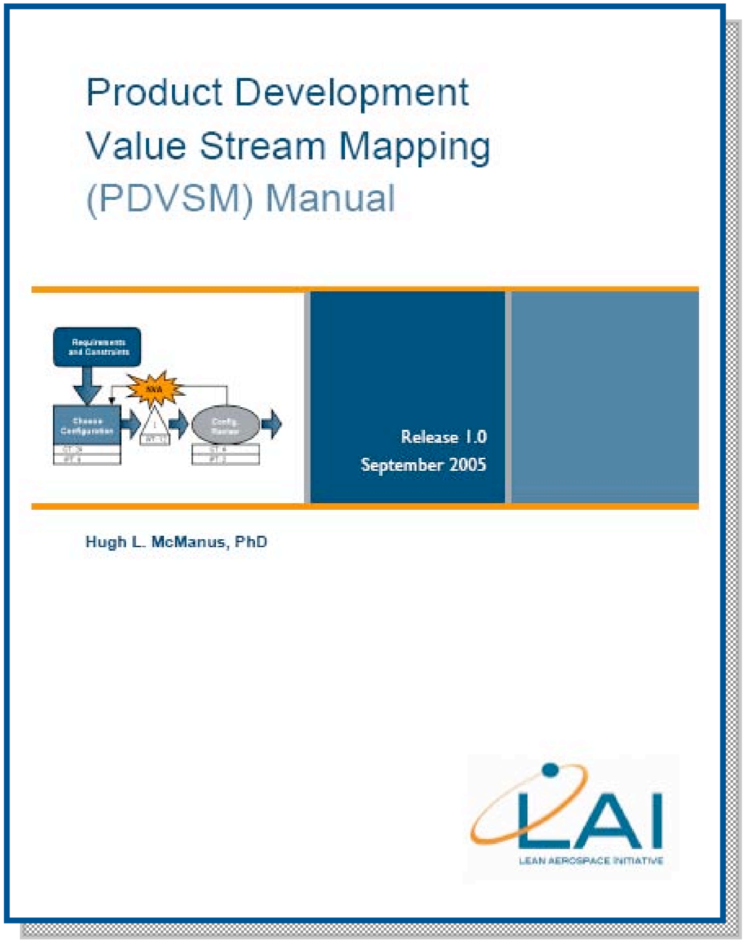
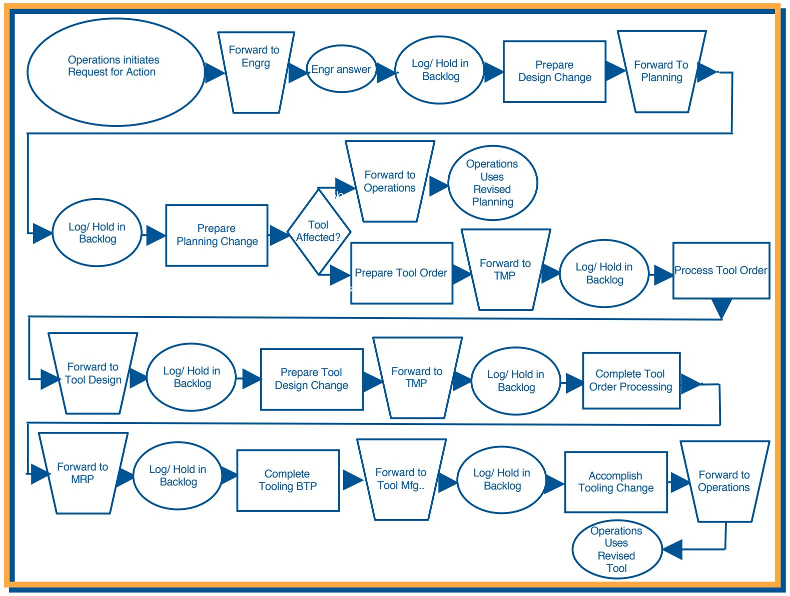
VSM Applied to Product Development



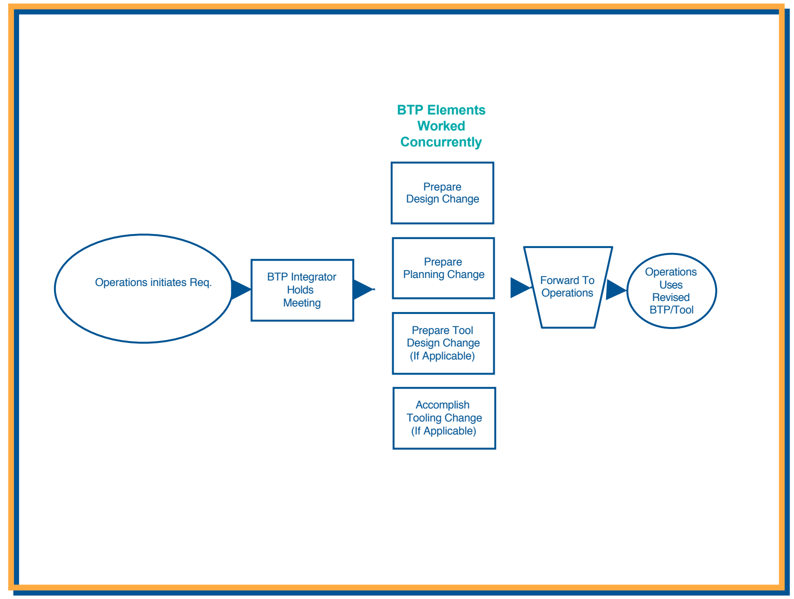
- **Same basic techniques apply**
- **Flows are knowledge and information flows rather than physical products**
- **Process steps may overlap or involve *planned* iterations**
- **Value added steps add or transform knowledge, *or reduce uncertainty (role of analysis steps)***
- **Quantifies key parameters for each activity (cycle time, cost, quality defects, inventory, etc.)**
- **Provides systematic method to improve a process by eliminating waste**

PDVSM Used For F16 Build-to-Package Process

Process Before Lean



Process After Lean



Single Piece flow, concurrent engineering, co-location

Courtesy of Lockheed Martin. Used with permission.
Source: "F-16 Build-T-Package Support Center Process", January 2000.

F-16 Lean Build-To-Package Support Center Results

- **Scope:** ***Class II , ECP supplemental, production improvements, and make-it-work changes initiated by production requests***
- **Target improvement:** ***Reduce average cycle-time by 50%***
- **Operational:** ***1999***
- **Future applications:** ***Pursuing concept installation in other areas***

849 BTP packages from 7/7/99 to 1/17/00

Category	% Reduction
Cycle-Time	75%
Process Steps	40%
Number of Handoffs	75%
Travel Distance	90%

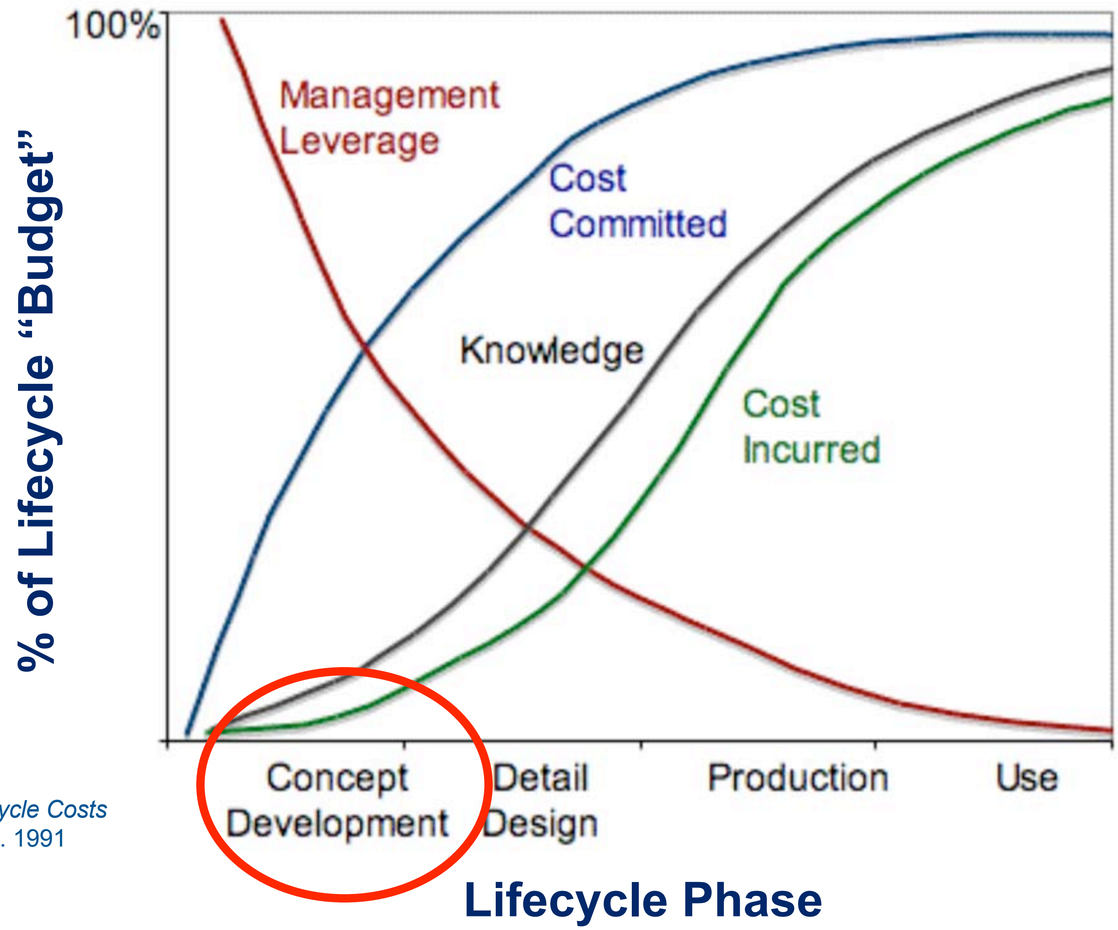
Courtesy of Lockheed Martin. Used with permission.
Source: "F-16 Build-T-Package Support Center Process", January 2000.

2 Key Take Aways

1. Lean thinking applies to the engineering process

2. Engineering plays a critical role in creating value in a lean enterprise

Focus on the Front End Where Critical Decisions Are Made



Adapted from Fabrycky, W. *Life Cycle Costs and Economics*. Prentice Hall, N.J. 1991

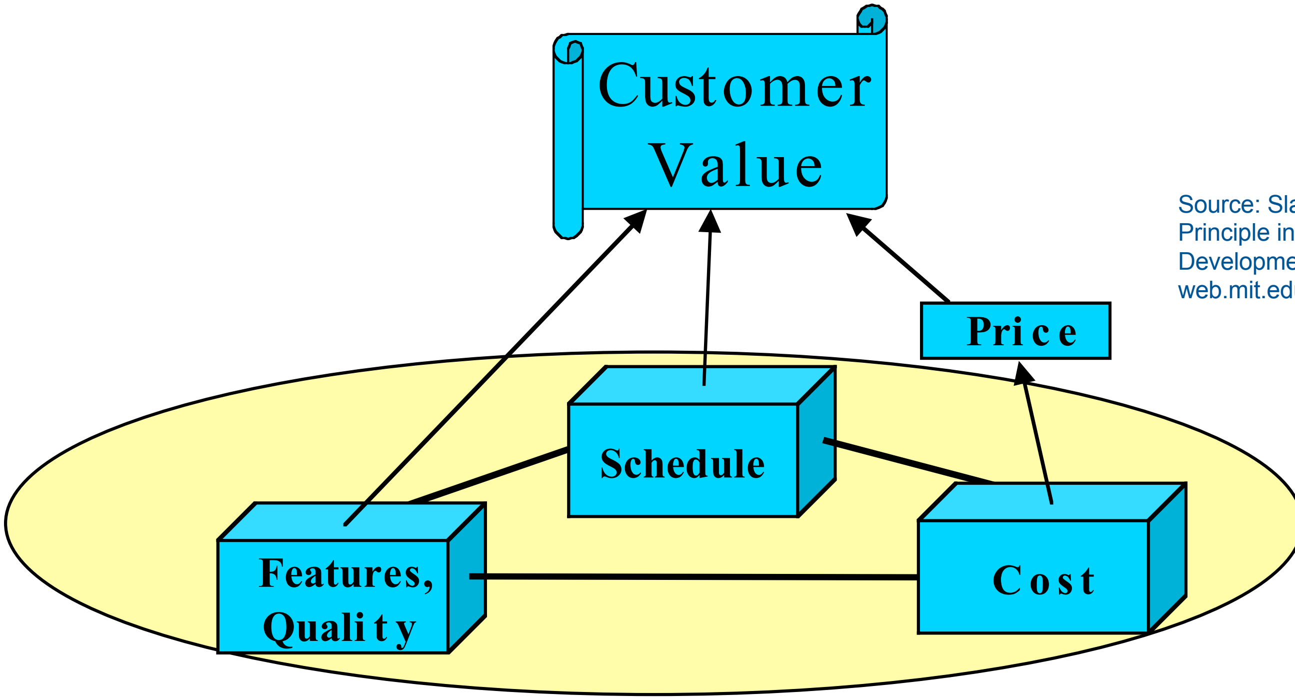
Lean Thinking Needs to Start With Engineering

Lean Engineering:
Doing the Right Thing Right

- Creating the right products…
  - Focus on the Customer
  - Shift resources to "up-front" concept design
- With effective enterprise and lifecycle integration…
  - Use lean engineering tools to create value throughout the enterprise and product lifecycle
- Using efficient engineering processes...
  - Apply lean thinking to eliminate wastes and improve cycle time and quality in engineering.

Ref: McManus, H.L. "Product Development Value Stream Mapping Manual" V1.0, LAI, Sep 2005

Creating the Right Products: Customer Defines Product Value



Source: Slack, R.A., "The Lean Value Principle in Military Aerospace Product Development", LAI RP99-01-16, Jul 1999. web.mit.edu/lean

Product Value is a function of the product

- **Features and attributes to satisfy a customer need**
- **Quality or lack of defects**
- **Availability relative to when it is needed, and**
- **Price and/or cost of ownership to the customer**

Engineering Drives Cost!

80% of a product's cost is determined by the engineering design:

- Number of parts / tolerances
- Assembly technique (fasteners, EB welding, co-cure)
- Processes (heat treat, shot peen, etc.)
- Tooling approach (matched metal dies, injection molding, etc.)
- Materials (titanium, aluminum, composites, etc.)
- Avionics / software
- Design complexity
- Design re-use

Engineers must make the right choices, early in the process, to insure customer satisfaction and low lifecycle costs.

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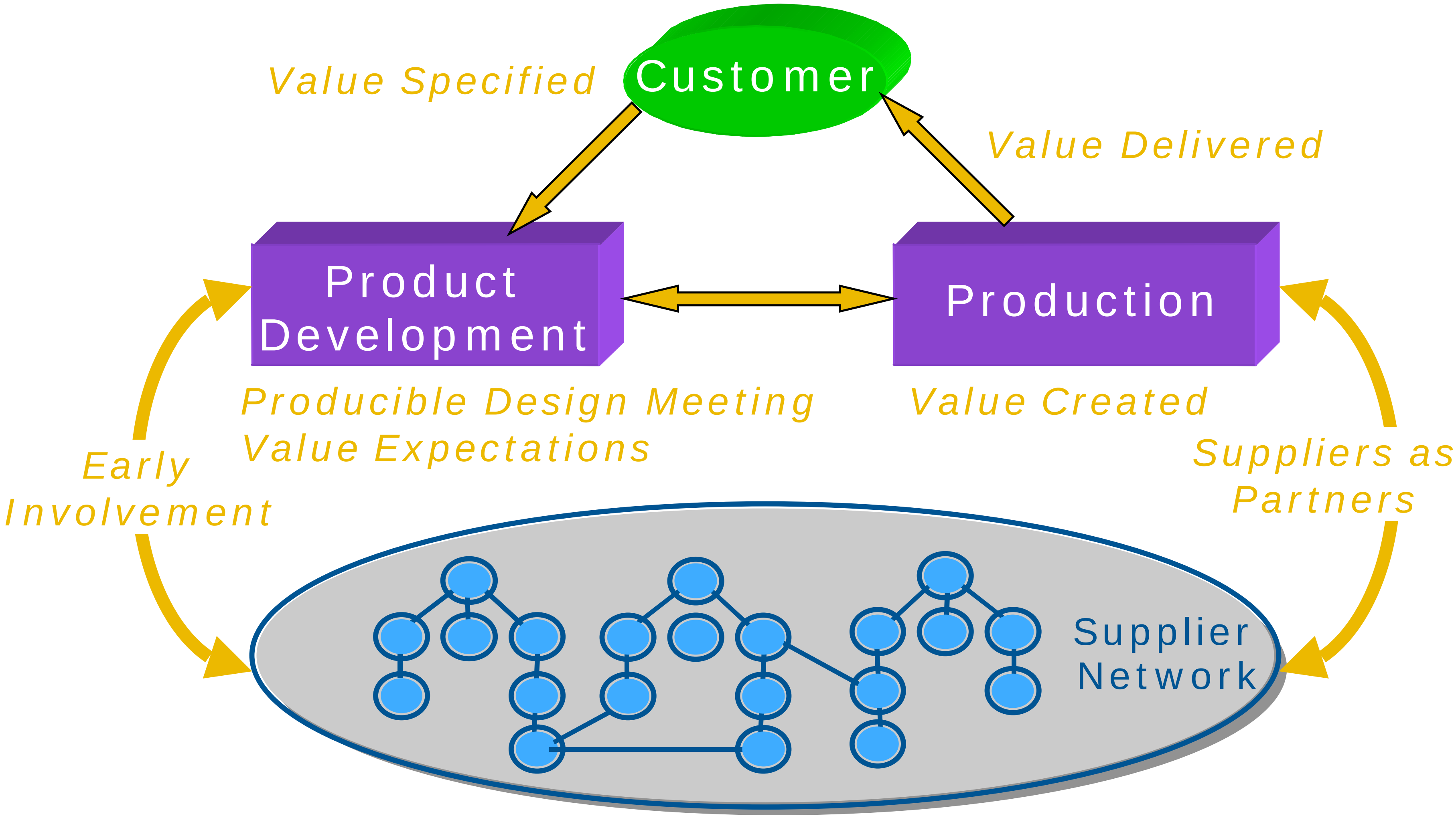
Don’t Forget the Suppliers!



Typically, 60-80% of Value Added by Suppliers

Integrated Product and Process Development - IPPD

- Preferred approach to develop producible design meeting value expectations
- Utilizes:
  - Systems Engineering: Translates customer needs and requirements into product architecture and set of specifications
  - Integrated Product Teams (IPTs): Incorporates knowledge about all lifecycle phases
  - Modern Engineering tools: Enable lean processes
  - Training: Assures human resources are ready

Capable people, processes and tools are required

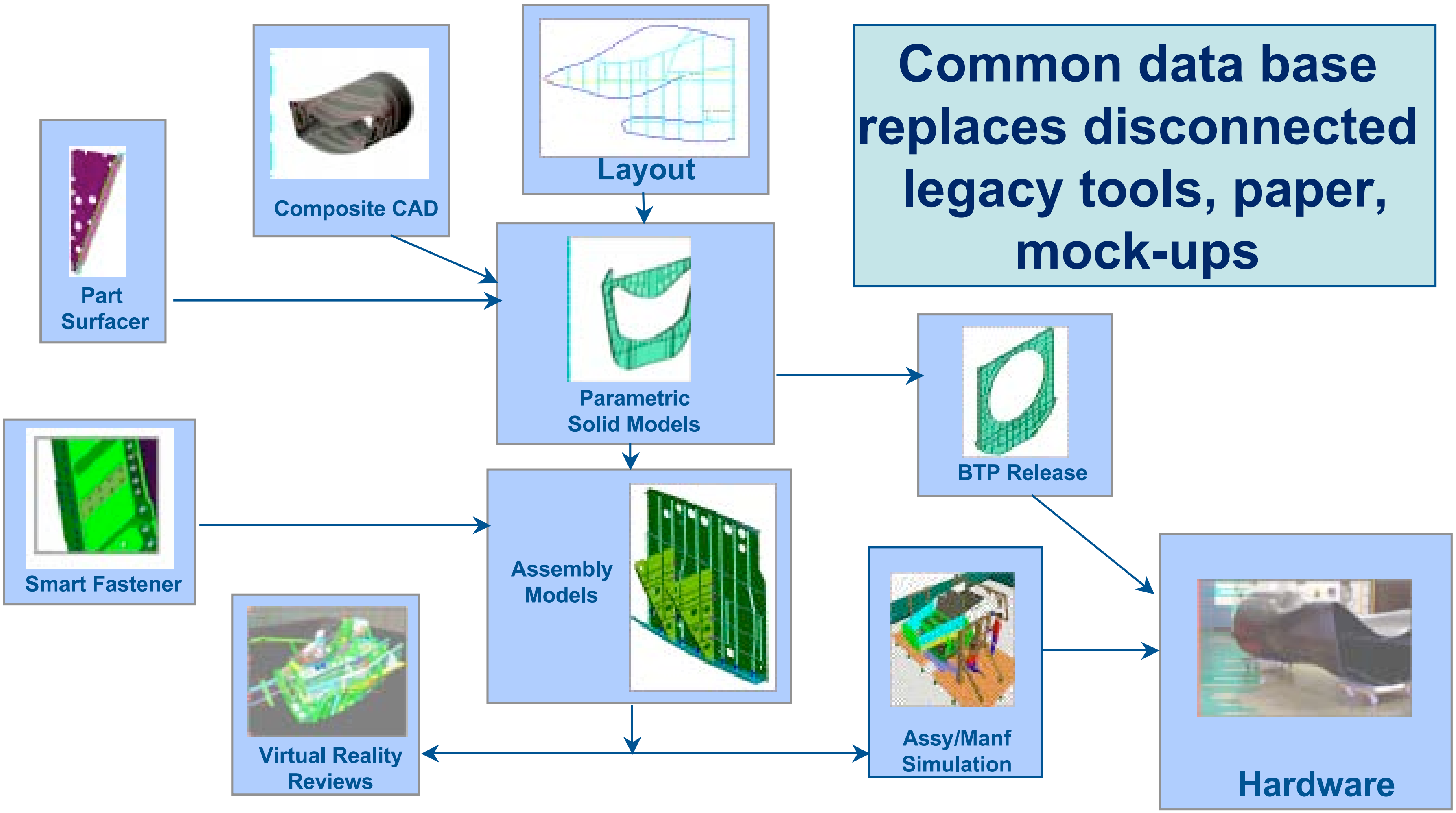
Tools of Lean Engineering

- Integrated digital tools reduce wastes of handoffs and waiting, and increase quality
  - Mechanical (3-D solids based design)
  - VLSIC (Very Large Scale Integrated Circuit) toolsets
  - Software development environments/Model-Based Engineering
- Production simulation (and software equivalents)
- Common parts / specifications / design reuse
- Design for manufacturing and assembly (DFMA)
- Dimensional/configuration/interface management
- Variability reduction
- Product Lifecycle Management (PLM) software

All of these tools enabled by people working together in Integrated Product Teams (IPTs)

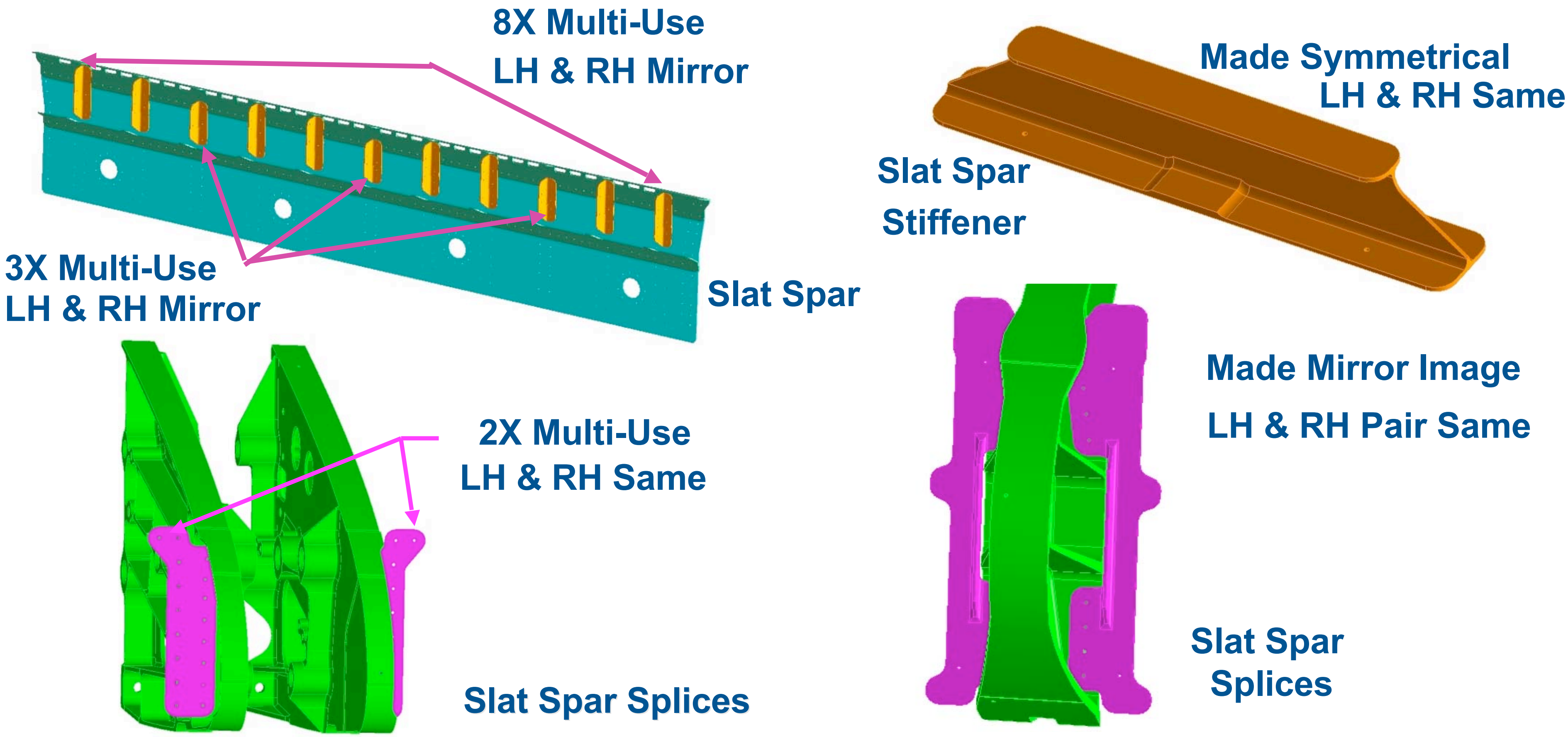
Integrated Digital Tools from Concept to Hardware

Common data base replaces disconnected legacy tools, paper, mock-ups



Source: John Coyle, The Boeing Company

Common Parts, Design Reuse



Reduces part cost and increases quality

Source: Ned Newman, The Boeing Company (C-17)

Part Count Reduction: DFMA

- Why reduce part count?
  - Reduce recurring & non-recurring cost
  - Reduce design, manufacturing, assembly, testing and inspection work
  - Reduce inventory
  - Reduce maintenance spares

- Sometimes requires "performance" trades, but not always – and cost and schedule savings are typically significant

Lego Simulation DFMA Exercise

Redesign the airplane! Rules:

- Satisfy customer
  - Moldline (outside shape) must remain *exactly* the same
  - Landing gear (and only landing gear) must be brown
  - In-service quality must improve
  - Increase delivery quantities
- Reduce manufacturing costs
  - Part count ($5/part)
  - Less parts = more capacity
- Incorporate suppliers
  - Innovations
  - Reduced part diversity (?)

Present your design to your facilitator
Demonstrate it satisfies all criteria

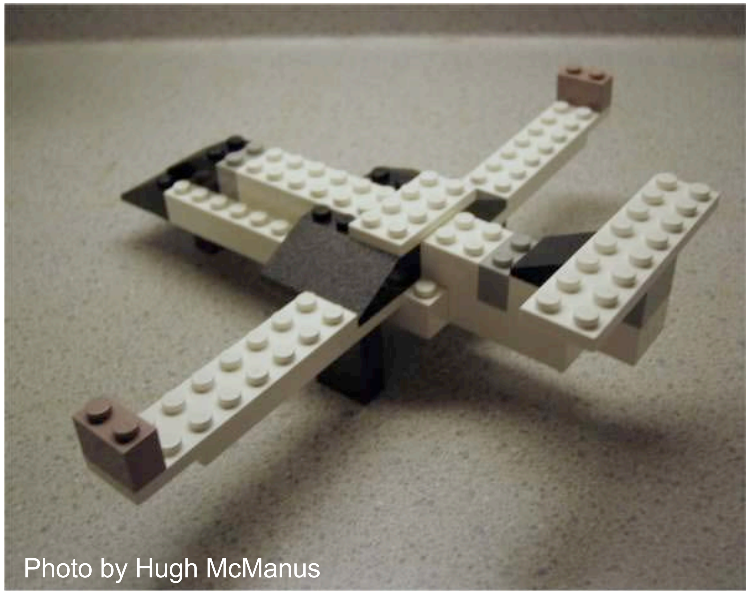
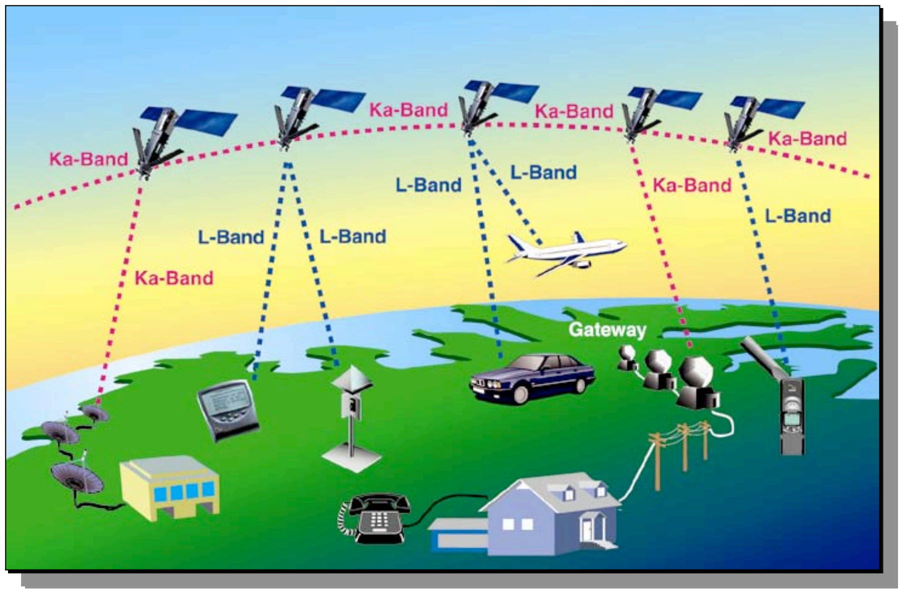


Photo by Hugh McManus

Lean Engineering in Practice

Courtesy of Boeing. Used with permission.

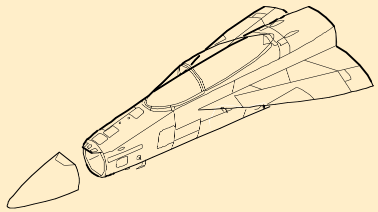
Now let's look at some real-world examples of lean engineering benefits…



Courtesy of Ray Leopold. Used with permission.

Part Count Reduction: DFMA

Forward Fuselage and Equipment



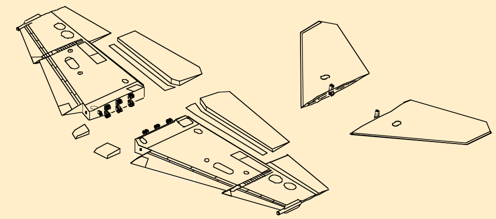
C/D Parts
5,907

E/F Parts
3,296

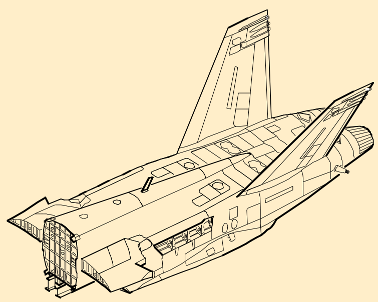
Wings and Horizontal Tails

C/D Parts
1,774

E/F Parts
1,033

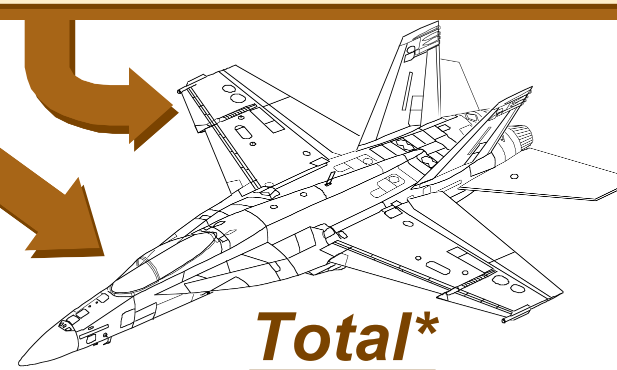


Center/Aft Fuselage, Vertical Tails and Systems



C/D Parts
5,500

E/F Parts
2,847



*Total**

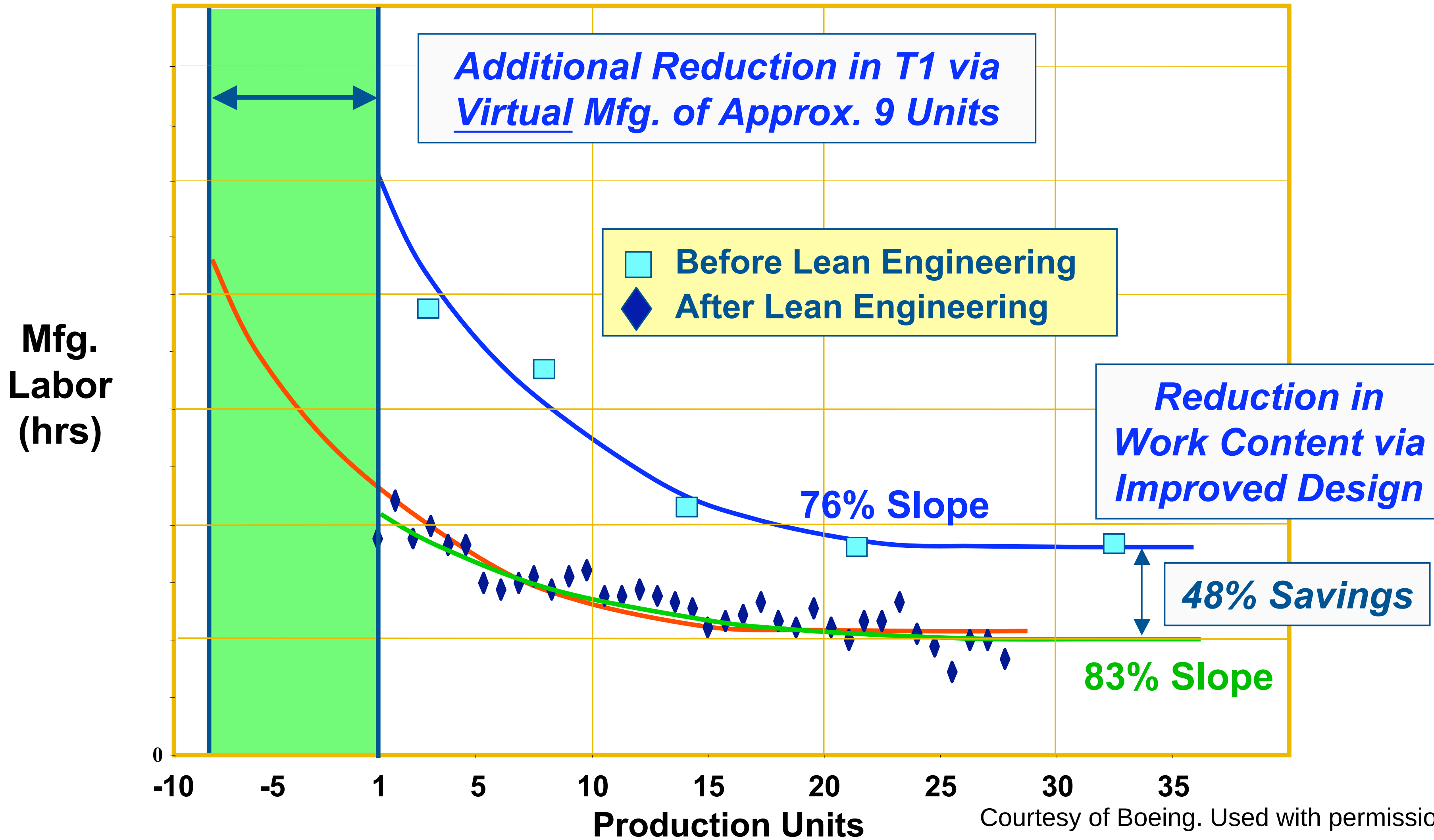
C/D Parts	E/F Parts
14,104	8,099

*Includes joining parts

F-18 E/F is 25% larger but has 42% fewer parts than C/D

Source: The Boeing Company

Lean Engineering Reduces Manufacturing Labor



Courtesy of Boeing. Used with permission.

Source: "Lean Engineering ", John Coyle (Boeing), LAI Executive Board Presentation, June 1, 2000

Lean Engineering Enables Faster and More Efficient Design

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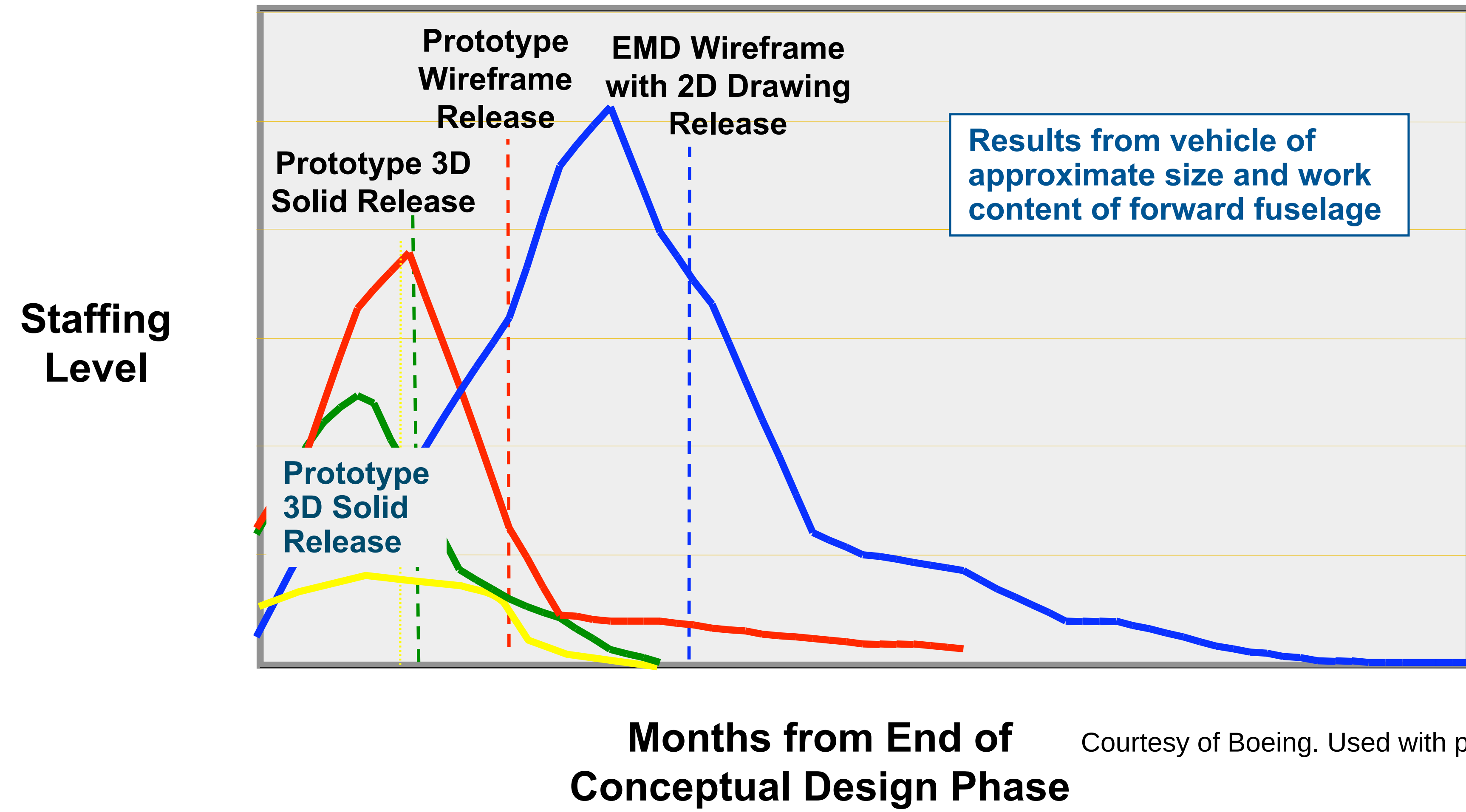
Forward Fuselage Development Total IPT Labor



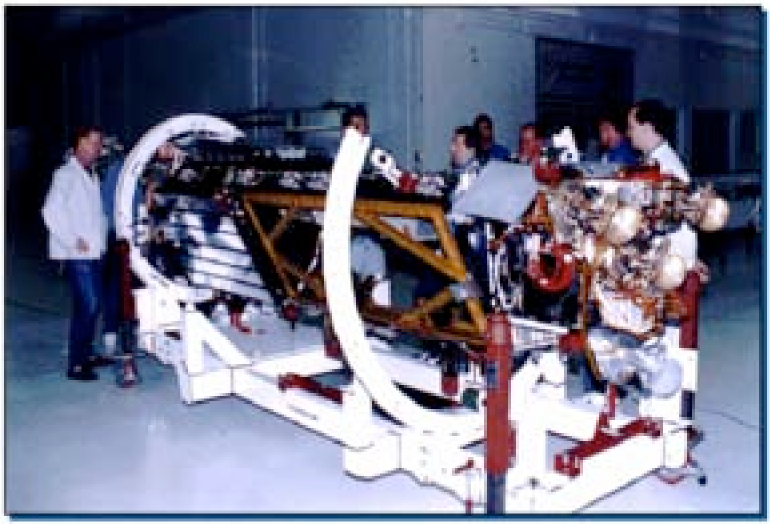
Courtesy of Boeing. Used with permission.

Source: "Lean Engineering ", John Coyle (Boeing), LAI Executive Board Presentation, June 1, 2000

Lean Engineering Enables Faster Delivery Times

Iridium Manufacturing

- Cycle time of 25 days vs. industry standard of 12-18 months
- Dock-to-Dock rate of 4.3 Days



Iridium Deployment

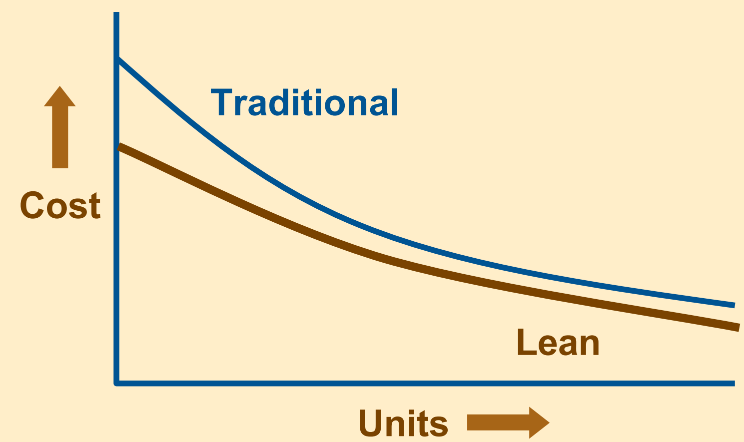
- 72 Satellites in 12 Months, 12 Days
- 14 Satellites on 3 Launch Vehicles, from 3 Countries, in 13 Days
- 22 Successful Consecutive Launches

Courtesy of Ray Leopold. Used with permission.

Lean Engineering Wrap Up

Lean Engineering
- Focus on Customer Value
- IPPD and IPTs
- Integrated Digital Design Tools
- Production Simulation
- DFMA
- Design Reuse & Commonality
- Variability Reduction

Affordability Through Lean



Lean Manufacturing
- High Performance Work Org
- Advance Technology Assembly
- Cycle Time Reduction
- Variability Reduction/SPC
- Value Stream Mapping
- Kaizen Events
- Operator Verification

Lean Supply Chain
- Supplier Base Reduction
- Certified Suppliers
- Suppliers as Partners
- Electronic Commerce/CITIS
- IPT Participation

Adapted from: "Lean Engineering ", John Coyle (Boeing), LAI Executive Board Presentation, June 1, 2000

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Notes

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