



Raytheon

Prepared for:  BOOTHROYD DEWHURST, Inc.
33rd International Forum on Design for Manufacture and Assembly

Why DFMA and Lean



Raytheon Integrated Defense Systems

September 11-12, 2017

Presenter: Mark Steudel

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Presentation Outline

- Raytheon introduction
- Why do DFMA and Lean on new product development
- A simple cost analysis will show the relationship between DFA and DFM and Lean and the cost savings opportunity.
- How does lean fit in with DFMA
- How DFMA measurably reduced or avoided costs or provided other benefits.
- Case studies
- Open discussion with attendees on their reasons for doing DFMA and the results.
- The business case and expectations in their company for DFMA with lean.



2018 Company Overview

RAYTHEON COMPANY – A TECHNOLOGY AND INNOVATION LEADER SPECIALIZING IN DEFENSE, CIVIL GOVERNMENT AND CYBERSECURITY SOLUTIONS THROUGHOUT THE WORLD.

- 2017 NET SALES: \$25 BILLION
- 64,000 EMPLOYEES WORLDWIDE
- HEADQUARTERS: WALTHAM, MASSACHUSETTS



ALIGNED WITH CUSTOMER PRIORITIES



MISSILE DEFENSE

Raytheon's broad portfolio of proven missile defense systems delivers multi-layered protection to protect the U.S. and its allies against a growing range of current and emerging threats.



COMMAND AND CONTROL

Raytheon is a leader in Command and Control systems, combining sensors and advanced networks to create entirely new ways of perceiving the world.



SENSORS AND IMAGING

Raytheon's proven radars and sensors work together to help experts see further, track longer and prepare smarter.



CYBER

Raytheon offers end-to-end capabilities that help customers protect information and infrastructures from cyber threats, and confidently navigate the cyber domain.



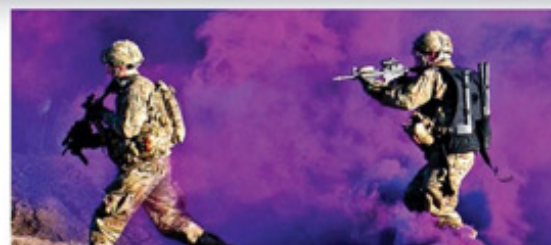
ELECTRONIC WARFARE

Raytheon's advanced electronic warfare systems and capabilities give our warfighters the continued strategic advantage to effectively and safely execute their missions in the modern threat environment.



PRECISION WEAPONS

Raytheon's reliable and cost-effective precision weapons systems incorporate advanced technologies that enable U.S. and allied military services to hit the target and protect their warfighters from evolving threats.



TRAINING SERVICES

Raytheon's innovative approaches and proven tools help customers successfully train staff, sustain skills and maintain operations for a wide variety of high-consequence missions worldwide.



MISSION SUPPORT

Raytheon supports high-consequence missions around the globe. Our innovative approaches and proven tools keep customers mission-ready while optimizing limited resources.

2018 Company Overview

GLOBAL PRESENCE ALWAYS THERE. DEDICATED TO OUR GLOBAL CUSTOMERS.

Raytheon Company is deeply committed to global partnerships, providing solutions and services to valued customers in more than 80 countries and building upon international relationships to best meet the national security and technology needs of nations around the world.



2018 Company Overview

BUSINESS HEADQUARTERS



2018 Company Overview

OUR BUSINESSES ARE ORGANIZED BY KEY MISSION AREAS

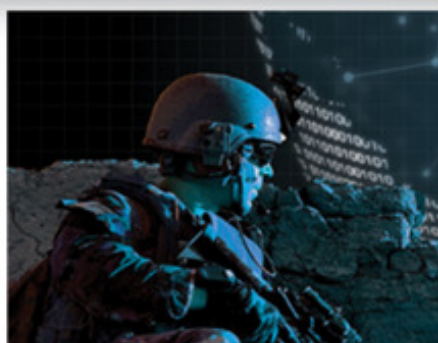
INTEGRATED DEFENSE SYSTEMS



IDS

Headquartered in Tewksbury, Massachusetts, Integrated Defense Systems specializes in air and missile defense, large land- and sea-based radars, and systems for managing command, control, communications, computers, cyber and intelligence. It also produces sonars, torpedoes and electronic systems for ships.

INTELLIGENCE, INFORMATION AND SERVICES



IIS

Headquartered in Dulles, Virginia, Intelligence, Information and Services designs and delivers solutions and services that leverage its deep expertise in cyber, analytics and automation. Software, systems integration, and the support and sustainment of Raytheon and other companies' systems for intelligence, military and civil applications are delivered across four domains: space, cyber, mission readiness, and multi-domain battlespace management command and control.

MISSILE SYSTEMS



RMS

Headquartered in Tucson, Arizona, Missile Systems is the premier global effects provider across broad addressable markets. The business designs, integrates, delivers and supports weapons systems for all missions spanning all domains, including interceptors for ballistic missile defense. It operates at the forefront of advanced technology development, including hypersonic weapons programs and directed energy systems. International operations include Raytheon UK, Raytheon ELCAN, and Raytheon Emirates.

SPACE AND AIRBORNE SYSTEMS



SAS

Headquartered in McKinney, Texas, Space and Airborne Systems is a leading provider of radar and sensor systems on airborne and space-based platforms. The business also provides communications, electronic warfare, high-energy laser solutions and special mission aircraft for the network-centric battlefield. Research advancements range from linguistics to quantum computing.

FORCEPOINT POWERED BY RAYTHEON



FORCEPOINT™

Forcepoint is transforming cybersecurity by focusing on what matters most: understanding people's intent as they interact with critical data and intellectual property wherever it resides. Forcepoint's Human Point System enables customers to understand the normal rhythm of user behavior and the flow of data throughout an organization to rapidly identify and eliminate risk. Based in Austin, Texas, Forcepoint protects the human point for thousands of enterprise and government customers in more than 150 countries.

2018 Company Overview

BROAD AND DEEP PORTFOLIO OF ADVANCED SOLUTIONS

INTEGRATED DEFENSE SYSTEMS



SPY-8(V)



Patriot®



C5I™



AN/TPY-2



Zumwalt

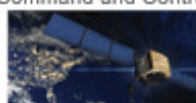
INTELLIGENCE, INFORMATION AND SERVICES



Cyber



Multi-Domain Battlespace Management
Command and Control



Space



Mission Readiness

MISSILE SYSTEMS



AMRAAM®



Tomahawk™



SM-3®



Excalibur®



ESSM®

SPACE AND AIRBORNE SYSTEMS



Airborne Radars



Electronic Warfare



High Energy Lasers



Intelligence, Surveillance and
Reconnaissance



Space Systems

FORCEPOINT



User and Data Security



Cloud Access Security



Network Security



Cross Domain and Critical
Infrastructure Solutions

Why do DFMA / Lean on new product development

- Cost

- Product affordability
- Lower product ownership “Sustainment”

- Time to Market

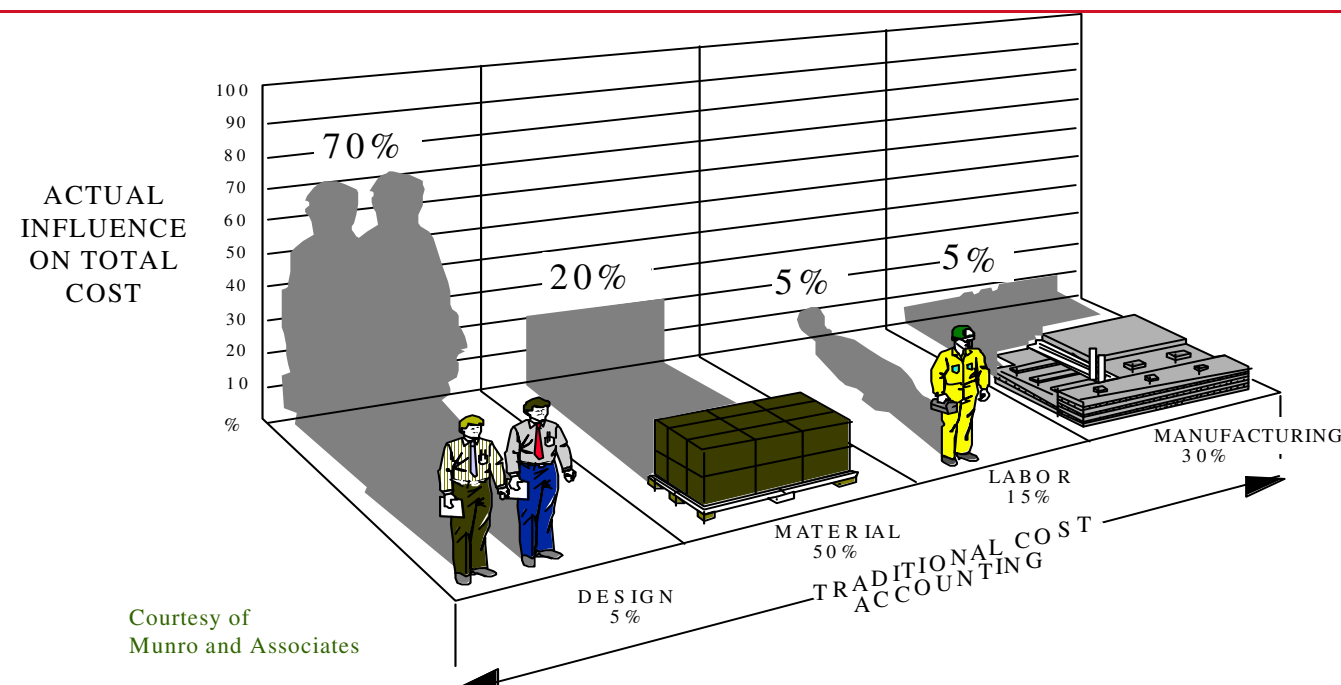
- Accelerate product development time
- Shorter production time per unit

- Quality

- Fewer parts and operation steps often provide higher manufacturing yield
- Simpler design often is more reliable and maintainable
- Higher level of product performance & reliability = Mission Assurance

- Innovation

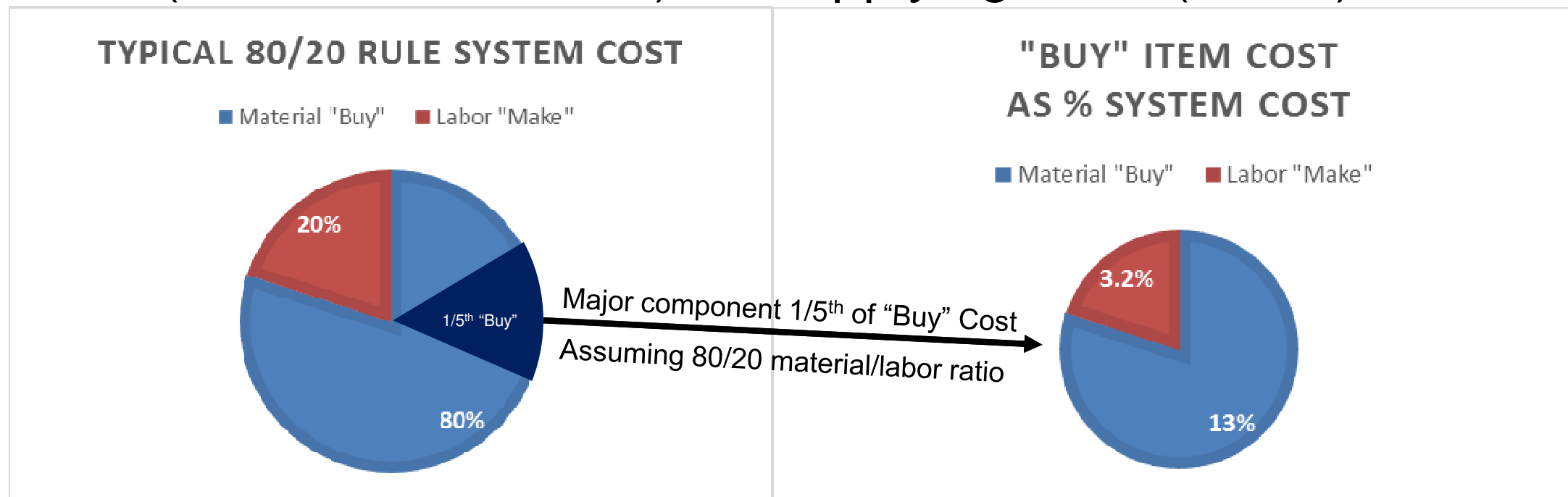
- Team based multi-discipline DFMA often identifies new ideas and methods



DFMA at the earliest design stages have the greatest impact

Why do DFMA / Lean on new product development

- Simple analysis shows cost savings opportunity between DFA and DFM (Material and Labor) and applying Lean (Labor)



- Lean can reduce the ~23% internal "Make" labor and "Buy" labor
- DFMA helps reduce both the ~80% material and ~20% labor costs

“DFMA” is...

Raytheon Design for Manufacturing and Assembly (DFMA) ensures the **manufacturability and affordability** of our products and processes while **achieving customer requirements**, with an emphasis on design, fabrication, assembly, integration, test, and sustainment.



DFMA Principles (Raytheon Tailoring)

1. Minimize the number of parts **and obsolescence**
2. Minimize the use of fasteners
3. Standardize / commonality
4. Avoid difficult components
5. Use modular assemblies and subassemblies
6. Use multifunctional parts
7. Minimize reorientations

9. Use self-locating features
10. Avoid special: tools, test and support equipment
11. Design and provide accessibility
12. Minimize process steps
13. **Design for service life and reliability**
14. **Minimize footprint in the field**
15. **Design for Exportability**
16. **Ergonomics & Safety**

Sustainment tailoring



DFMA Objective & Principles

- Objective of DFMA is to develop the best product or process design that meets:
 - All requirements & has competitive quality and cost
 - Avoids foreseeable downstream problems
- DFMA is conducted using the **DFMA Principles** to impart discipline and thoroughness
- DFMA uses cross-functional teams applying a broad knowledge base to:
 - Design hardware, software, and processes
 - Build teamwork with a focus on specific technology integration
 - Foster interactive communication, stimulate numerous alternatives, and resolve problems quickly

Our customers are demanding affordable products

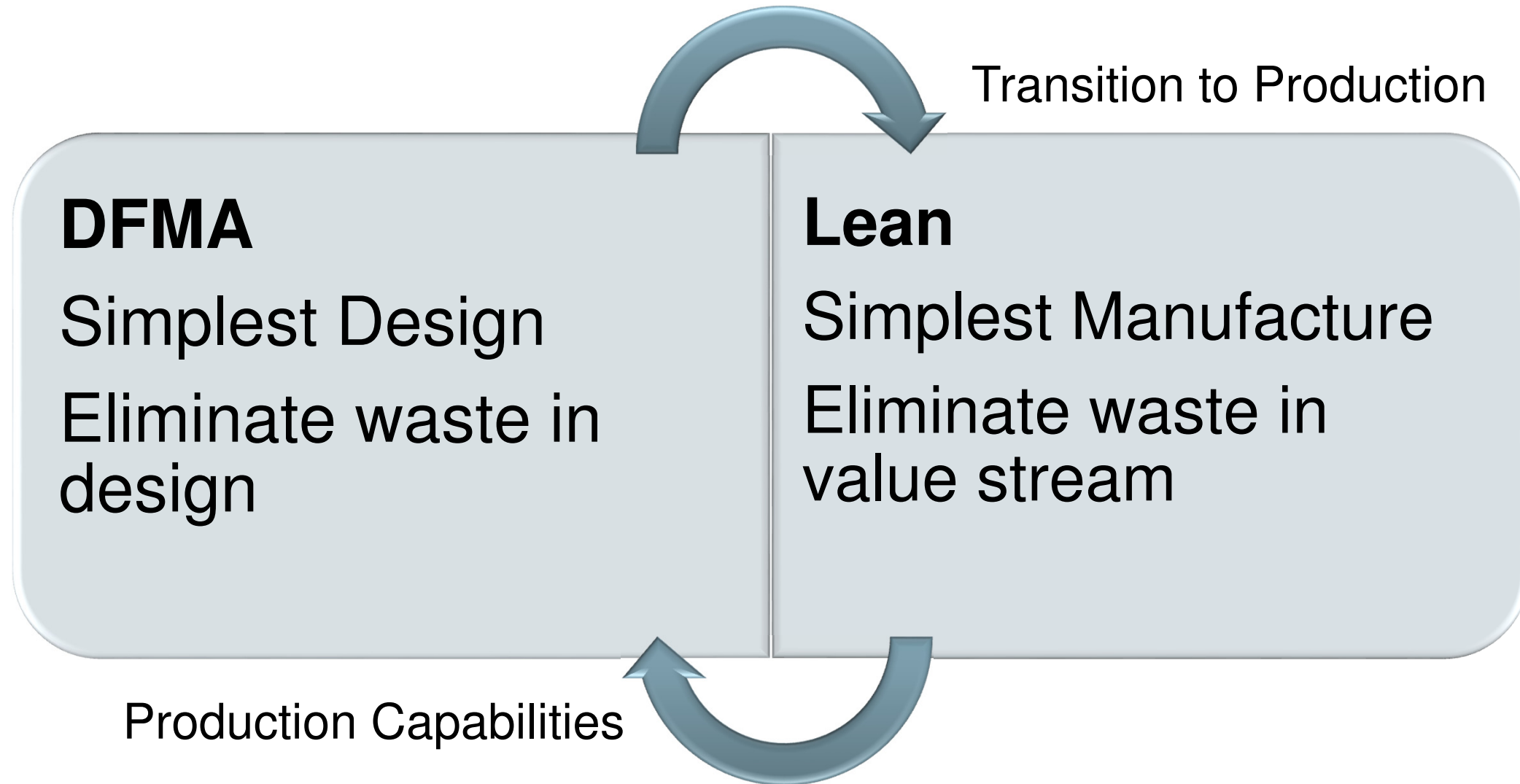
“DFMA” is...

- Wikipedia: **DFMA** is used as the basis for **concurrent engineering** studies to provide guidance to the design team in simplifying the product structure, to reduce manufacturing and assembly costs, and to quantify improvements. The practice of applying DFMA is to **identify, quantify and eliminate waste or inefficiency in a product design**. **DFMA is therefore a component of Lean Manufacturing**. DFMA is also used as a benchmarking tool to study competitors' products, and as a should cost tool to assist in supplier negotiations.^[1]

Source 1. Boothroyd, G., Dewhurst, P. and Knight, W., "Product Design for Manufacture and Assembly, 2nd Edition", Marcel Dekker, New York, 2002.

**A Ph.D. DFMA supplier team member defined it as
“Using data to drive design”**

DFMA and Lean interrelationship



Lean - Lean Enterprise Institute

- Maximize customer value while minimizing waste.
- ...optimizing the **flow of products** and services through entire value streams that flow horizontally across technologies, assets, and departments to customers
- Respond to changing customer desires with high variety, high quality, low cost, fast throughput times.
- **Eliminating waste along entire value streams**, instead of at isolated points, creates processes that need less human effort, less space, less capital, and less time to make products and services at far **less costs** and with much **fewer defects**, compared with traditional business systems.

Lean means creating more value for customers with fewer resources

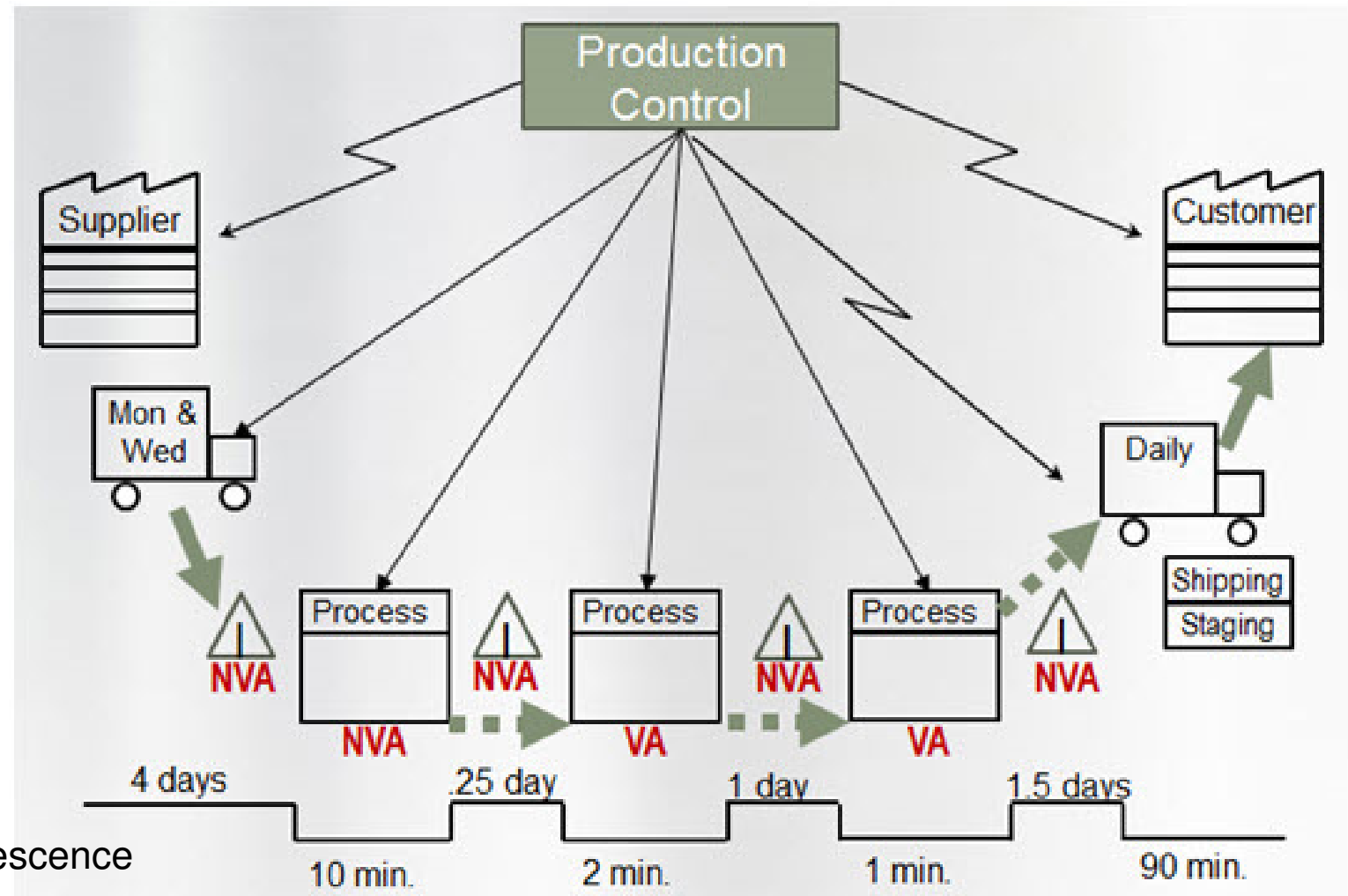
Lean - Lean Enterprise Institute

The five-step thought process for guiding the implementation of lean techniques is easy to remember, but not always easy to achieve:

1. Specify value from the standpoint of the end customer by product family.
2. Identify all the steps in the value stream for each product family, eliminating whenever possible those steps that do not create value.
3. Make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer.
4. As flow is introduced, let customers pull value from the next upstream activity.
5. As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, begin the process again and continue it until a state of perfection is reached in which perfect value is created with no waste.

Lean means creating more value for customers with fewer resources

Lean – Value Stream Mapping



DFMA Principles:

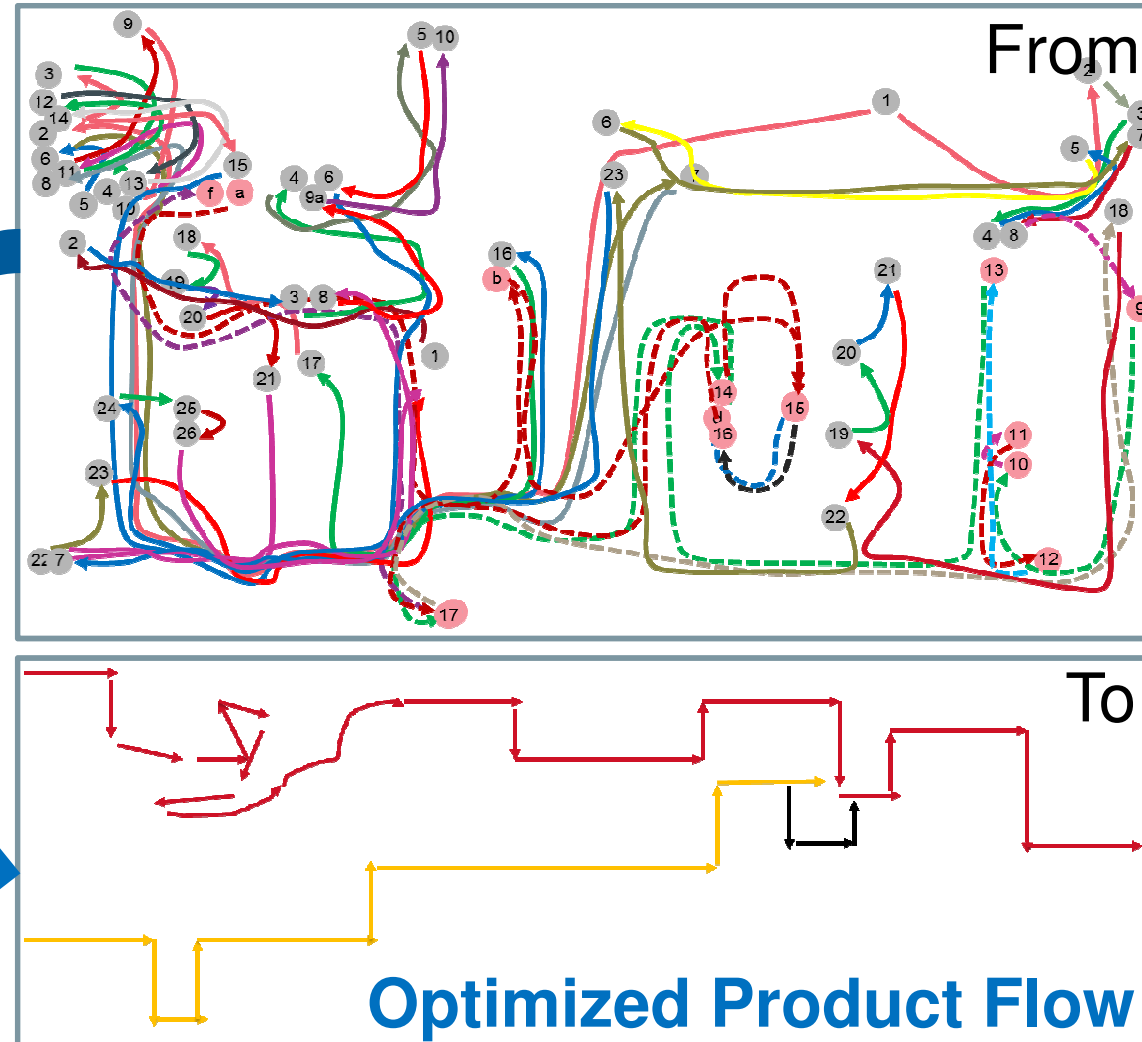
- 1. Minimize the number of parts and obsolescence
- 12. Minimize process steps

Lean means creating more value for customers with fewer resources

Lean – Spaghetti Diagram



DFMA Principles:
 7. Minimize reorientations
 12. Minimize process steps



Lean means creating more value for customers with fewer resources

Lean – The Seven Wastes

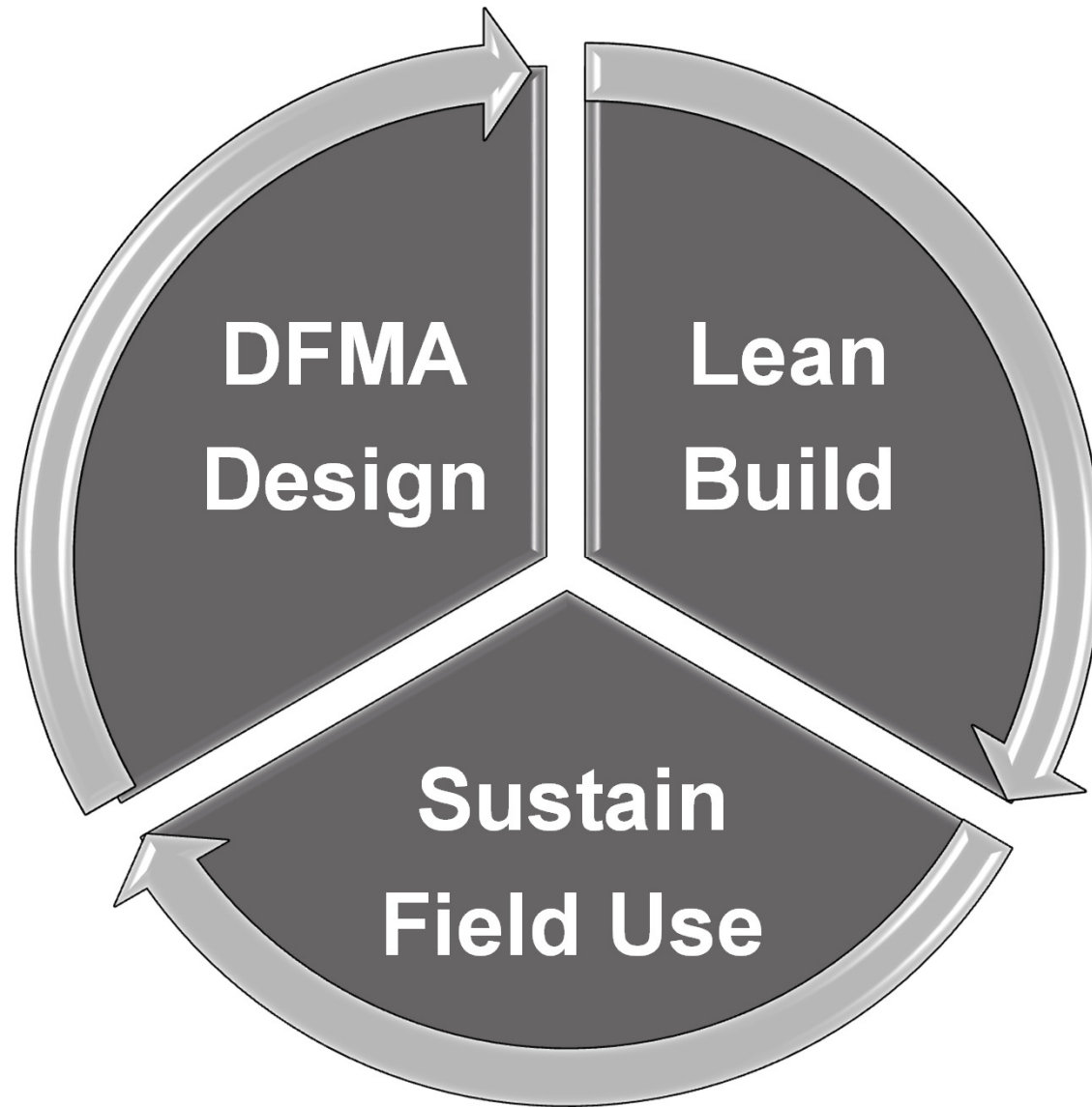


1. **D**efects
2. **O**verproduction
3. **T**ransportation
4. **W**aiting
5. **I**nventory
6. **M**otion
7. **P**rocessing

DOTWIMP, COMMWIP, or TIMWOOD

The worst of all the 7 wastes is overproduction because it includes in essence all others and was the main driving force for the Toyota JIT system, they were smart enough to tackle this one to eliminate the rest.

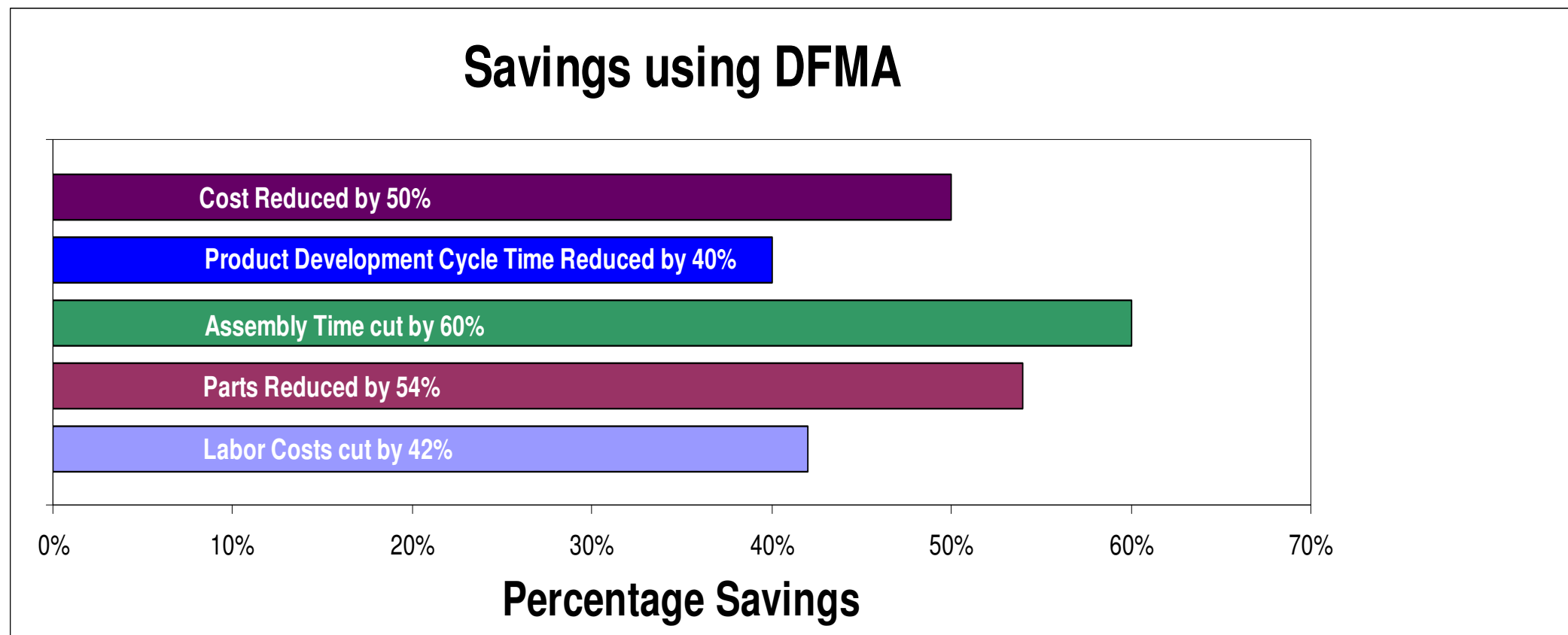
How does lean fit in with DFMA



- DFMA simplifies the parts and operations steps for build, drives design to use better parts and processes for higher yield
- Lean makes the manufacturing plan visible, optimizes how to build, and eliminates waste
- Sustainment provides feedback on product use and improvements customers may want

DFMA reduced costs or other benefits

Boothroyd Dewhurst data



DFMA/S done at earliest design stages will enable programs to better meet Cost and Schedule

Source Boothroyd-Dewhurst

DFMA reduced costs or other benefits

Boothroyd Dewhurst data

DFA Software Average Reductions

Labor Costs	42%
Part Count	54%
Separate Fasteners	57%
Weight	22%
Assembly Time	60%
Assembly Cost	45%
Assembly Tools	73%
Assembly Operations	53%
Product Development Cycle	45%
Total Cost	50%

Results compiled from over 100 published case studies

<http://www.dfma.com/software/dfma.asp>

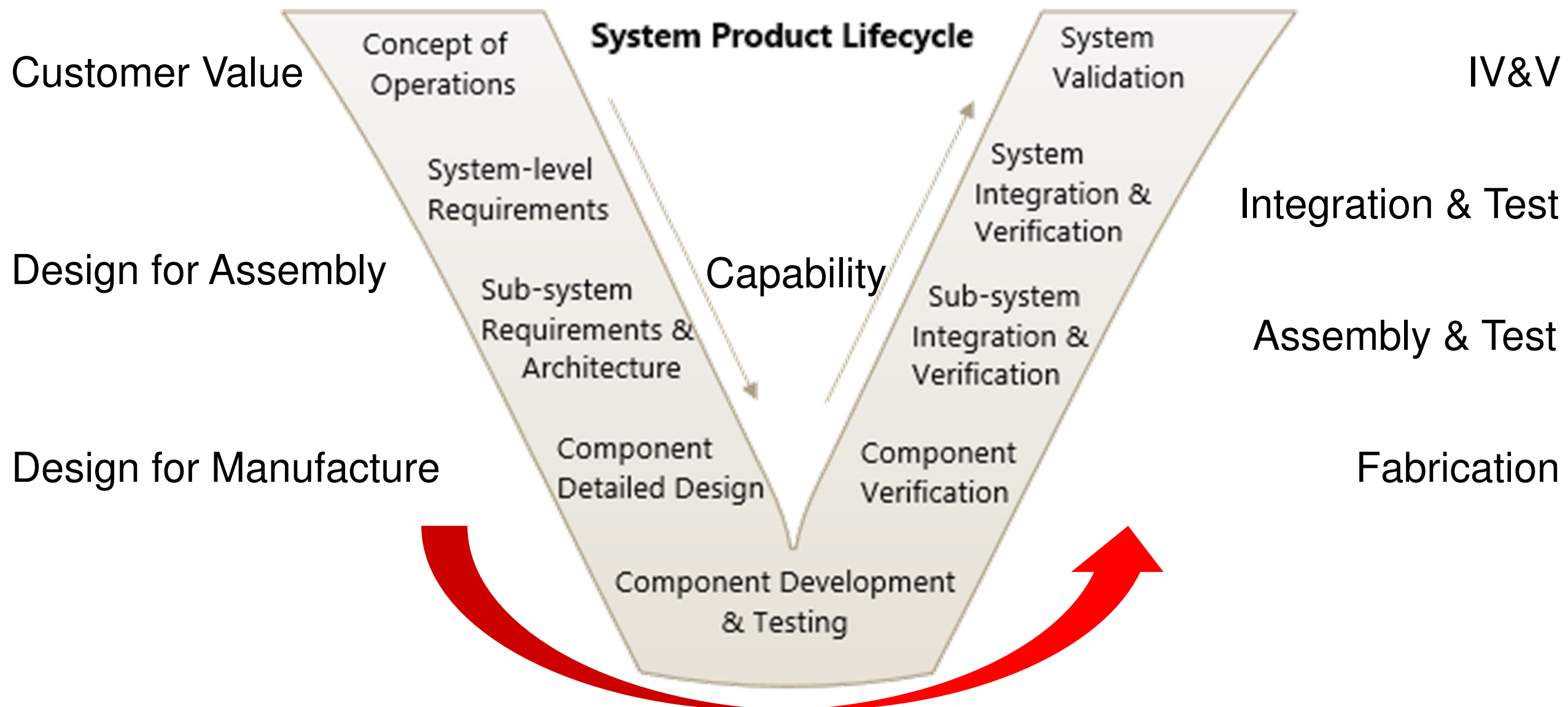
Raytheon results

Total Cost 31% average

Other results not discretely measured:

- Improved yield and quality
- Part count reductions
- Operation steps reduced
- Weight & corrosion reduction
- Reduced schedule risk
- Improved manufacturing planning
- Better 1st article and production start
- Reduced waste in value stream
- Over 500 DFMA projects completed

System Engineering “V” context for DFMA & Lean

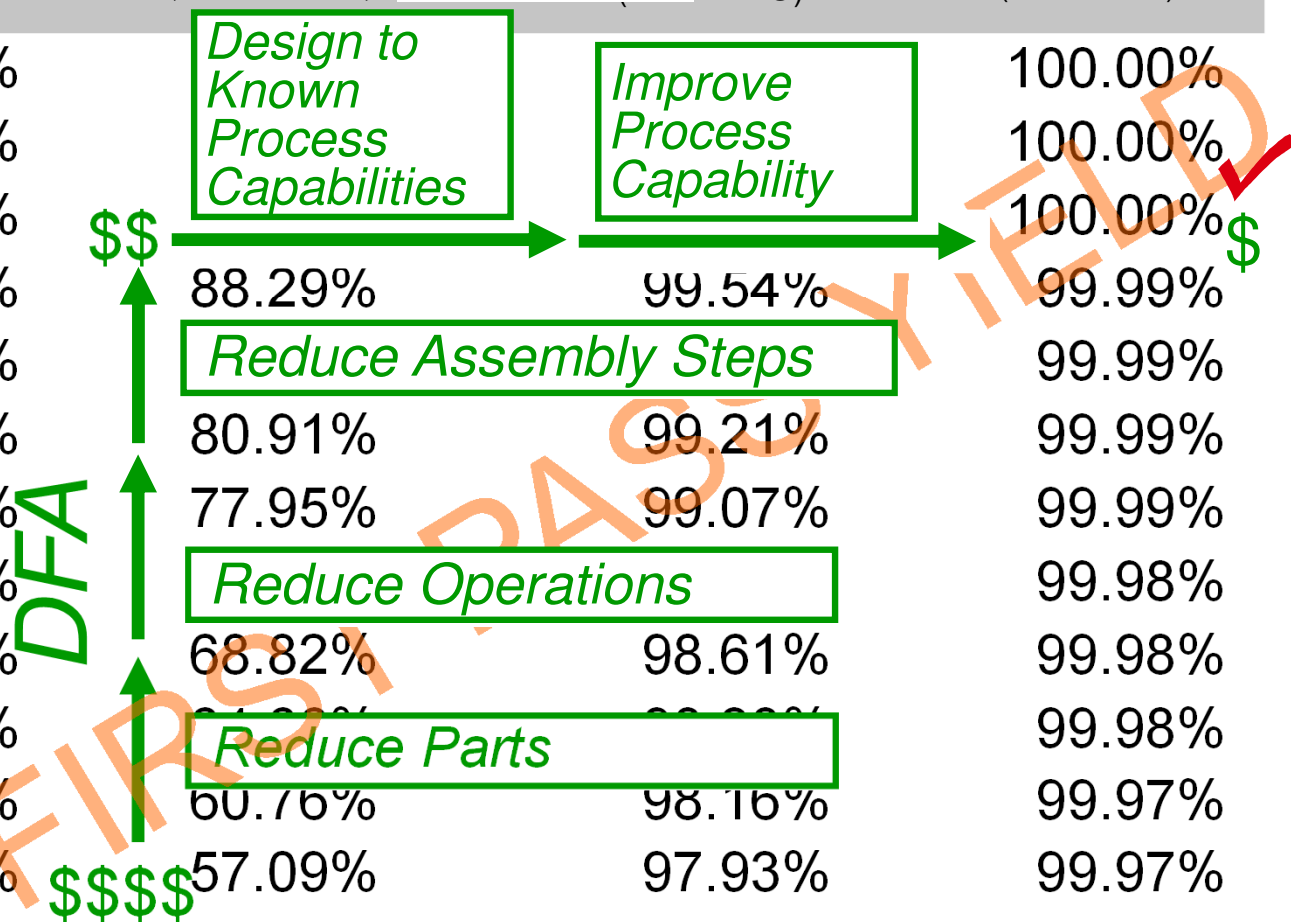


CT, Q, Yield, Capacity, Throughput

DFMA reduced costs or other benefits

OPPORTUNITIES

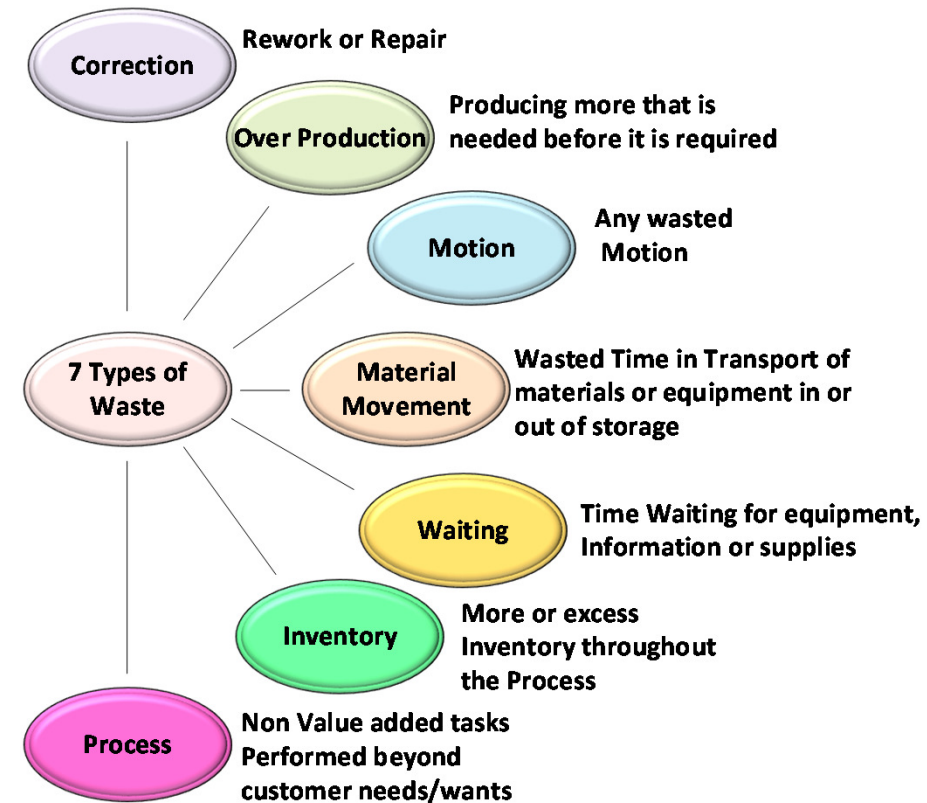
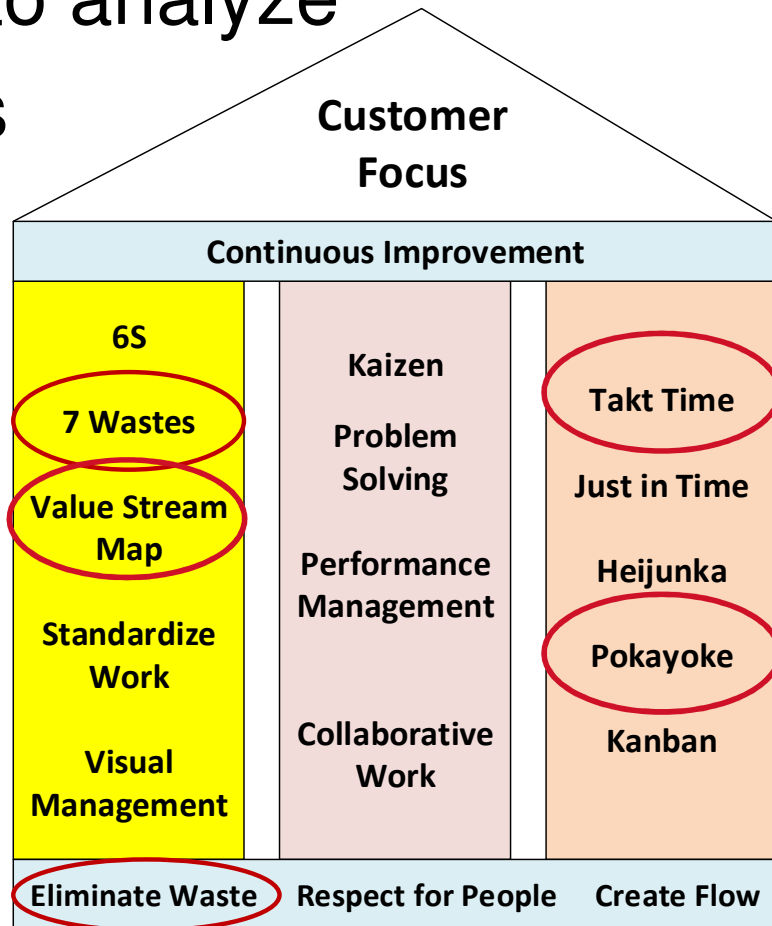
# of parts or steps	$\pm 3\sigma$ (69100 DPMO)	$\pm 4\sigma$ (6200 DPMO)	<i>DFM</i> 5 σ (DPMO)	$\pm 6\sigma$ (3.4 DPMO)
1	93.32%			100.00%
10	50.08%			100.00%
12	43.61%			100.00%
20	25.09%	88.29%	99.54%	99.99%
30	12.56%			99.99%
34	9.53%	80.91%	99.21%	99.99%
40	6.29%	77.95%	99.07%	99.99%
50	3.15%			99.98%
60	1.58%	68.82%	98.61%	99.98%
70	.79%			99.98%
80	.40%	60.76%	98.16%	99.97%
90	.20%	57.09%	97.93%	99.97%



Incorporation of Lean Manufacturing Initiatives.

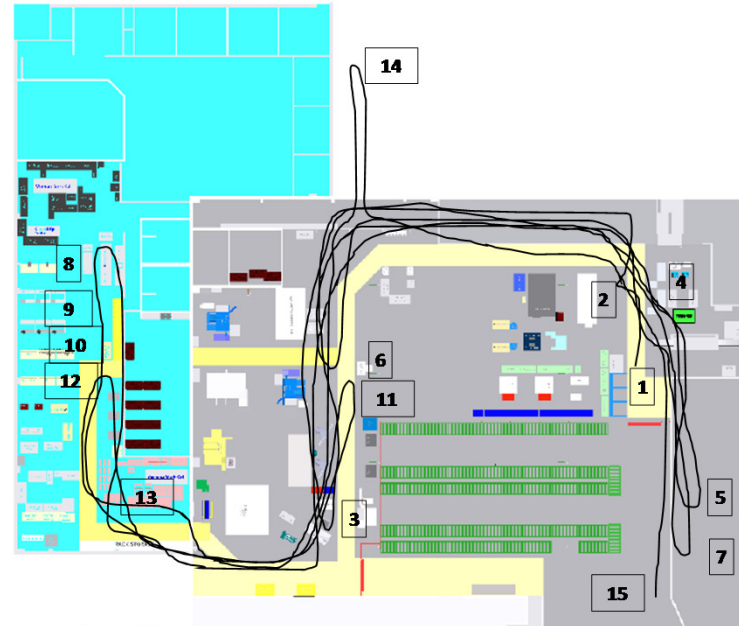
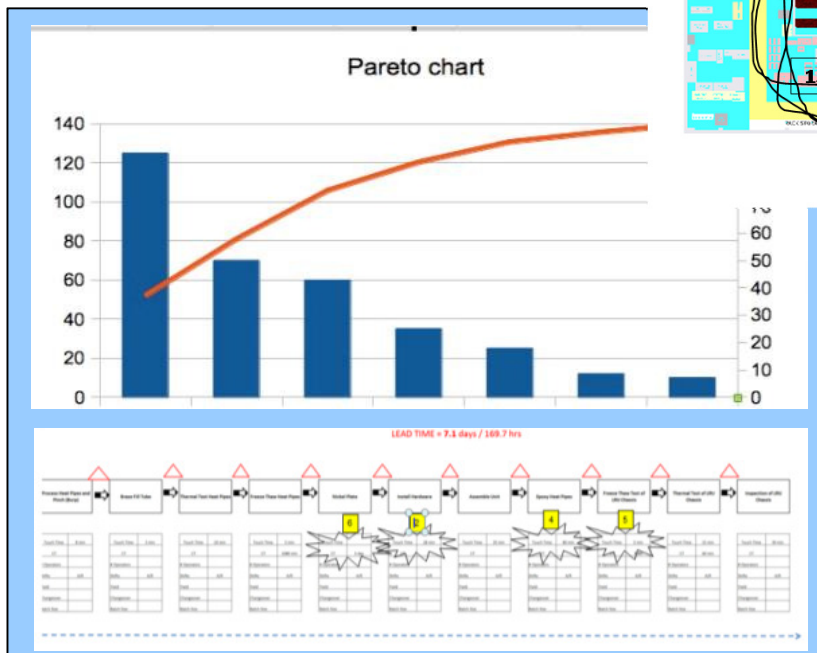
- Value stream mapping
- Visual sources of data to analyze
- Simul8 Process Models
- 3D workflow models
- Visual management

Design & Manufacturing process optimization



Case Study Component DFMA with Lean

Value Stream Map



Physical Process Map (Spaghetti Diagram)

Design for Manufacturing and Assembly

• Challenge

Objective: Reduce Cost and Weight

- Identify cost and yield improvements through collaboration between Raytheon and supplier to meet Affordability Targets

- Identify alternative manufacturing methods and sources

Overall Goal:

- Improve affordability of chassis to improve future sales

- At least 30% Cost reduction from target baseline

• Approach

- Apply Design for Manufacturing and Assembly (DFMA) principles using the DFMA Workshop approach

- Applied Lean principles, VSM

• Process

- Engaged multiple programs Design team and independent SMEs

- Leveraged manufacturing and test process capabilities

- Brainstormed over 31 improvement ideas parts, process changes and labor

- Prioritized ideas by ease and impact assessment

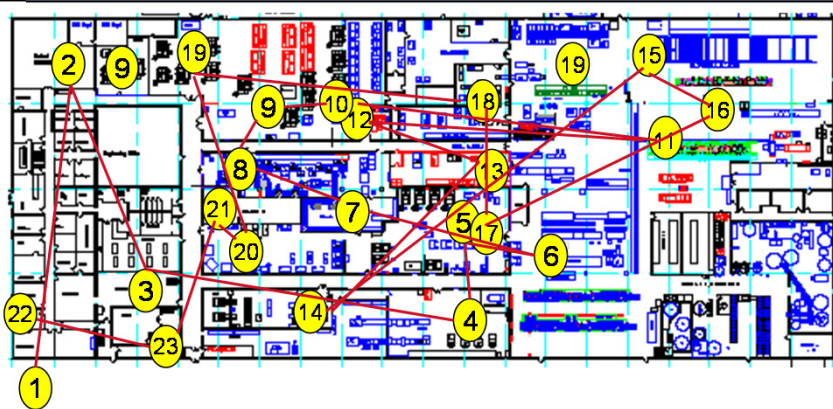
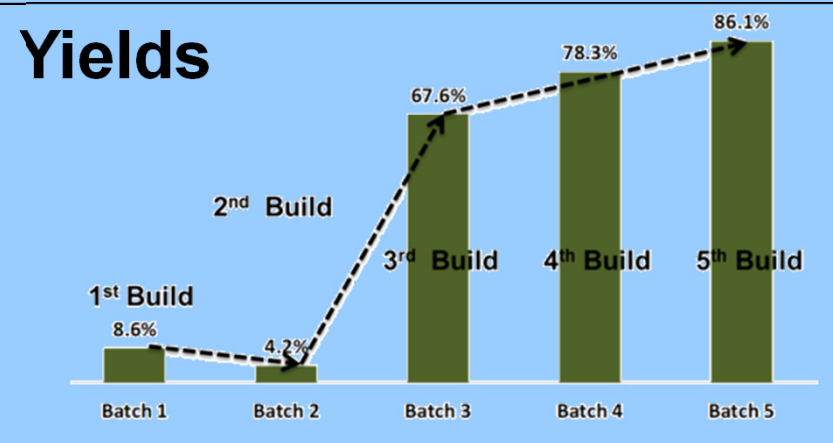
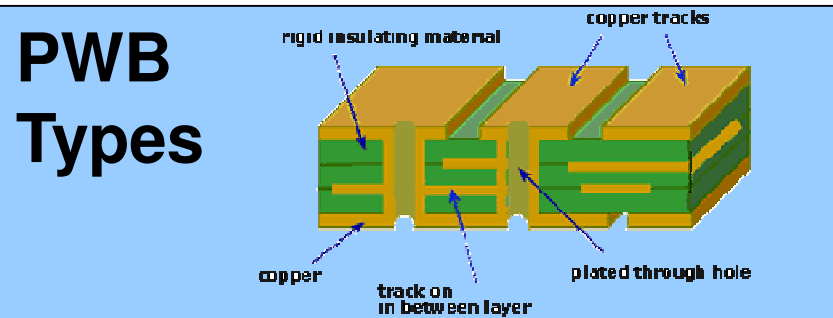
- Created outbrief for cost reduction initiatives

• Results

- **43%** cost reduction and **31%** parts reduction

Early supplier DFMA including Lean Methods

Case Study Component DFMA with Lean



Design for Manufacturing and Assembly

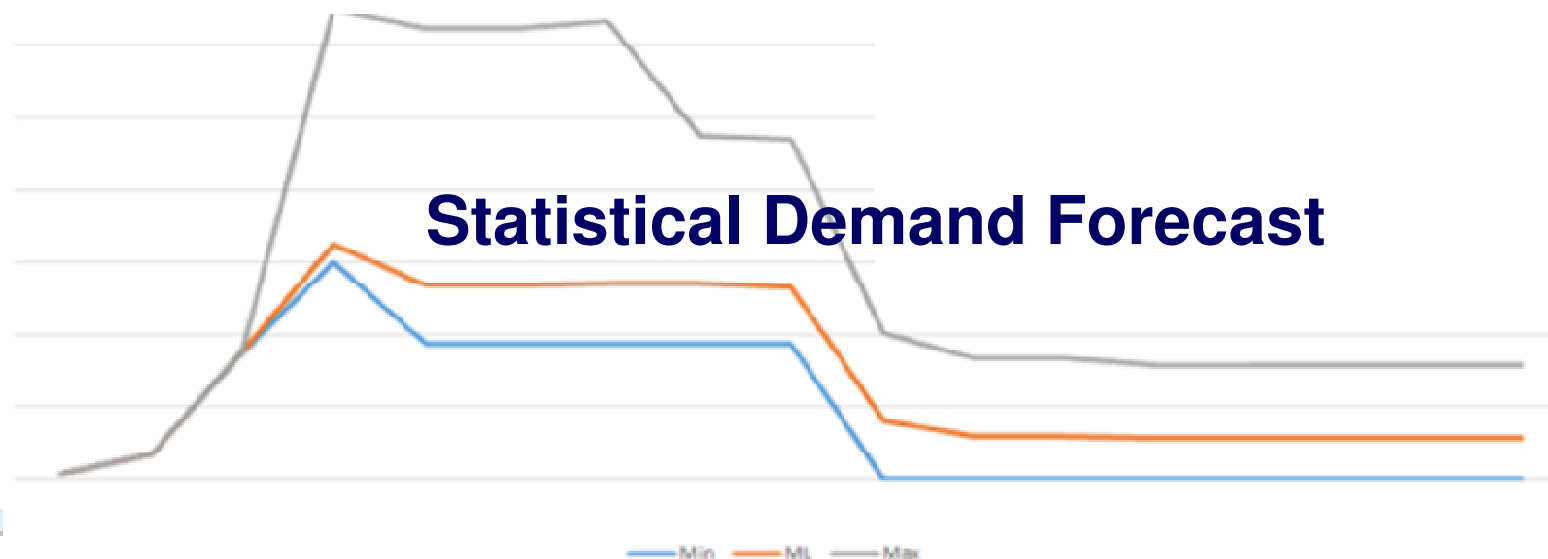
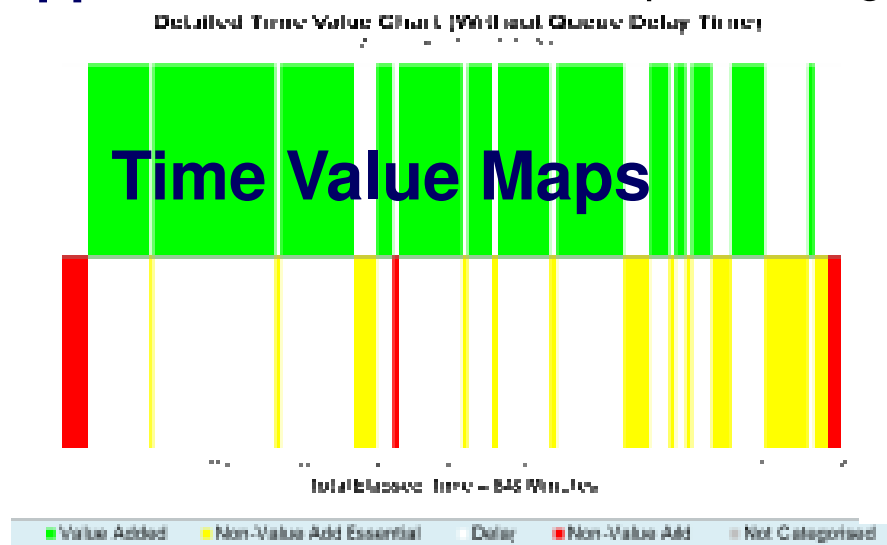
- **Challenge**
 - Need more affordable PWBs to improve Business Capture
 - Goal: 30% to 90% Cost reduction from baseline pricing
- **Approach**
 - Apply Design for Manufacturing and Assembly (DFMA) principles using the DFMA Workshop approach with Lean assessment
- **Process**
 - Engaged Design team and independent SMEs
 - Brainstormed over 56 improvement ideas
 - Prioritized ideas by ease and impact assessment
 - Created outbrief for cost reduction initiatives
- **Results**
 - Parts /Material reduction of 4 layers on PWB
 - Increase panel utilization (#Parts per panel)
 - Eliminate and optimize plating
 - Eliminate features and relax non critical material finish
 - **PWB–28% cost reduction**

Early supplier DFMA including Lean Methods

Case Study Component DFMA with Lean

Challenge: Supplier cost does not meet affordability targets and limits future potential sales

Approach: DFMA Workshop including Lean Methods



- Brainstormed over **100** improvement ideas
- Mapped manufacturing value stream
- Walked the physical process (Up & down stair flights)
- Prioritized ideas by ease and impact assessment
- Provided cost reduction initiative plan
- Savings at least **40%** with **Significant yield improvements**

Open discussion

- Attendees reasons for doing DFMA and the results



Questions



Raytheon

Back Up

The author

Mark Steudel



- Raytheon Company IDS DFSS/DFMA Lead
- Mark has over 30 years of product design development and leadership experience, is a member of the Raytheon Mechanical Engineering Directorate, and is a certified Raytheon Six Sigma Expert. Presently Mark is improving product affordability by leading DFMA/DFSS workshops to optimize products and manufacturing processes for cost, quality, producibility, and on time delivery. Previously Mark was the Test Director leading the environmental requirement verification for a program at Aberdeen, DPG/UTTR, and White Sands Missile Range. Mark holds a BS in Mechanical Engineering from Bucknell University and a MSIE in Engineering Management from Northeastern University

Abstract “*Why DFMA and Lean*”

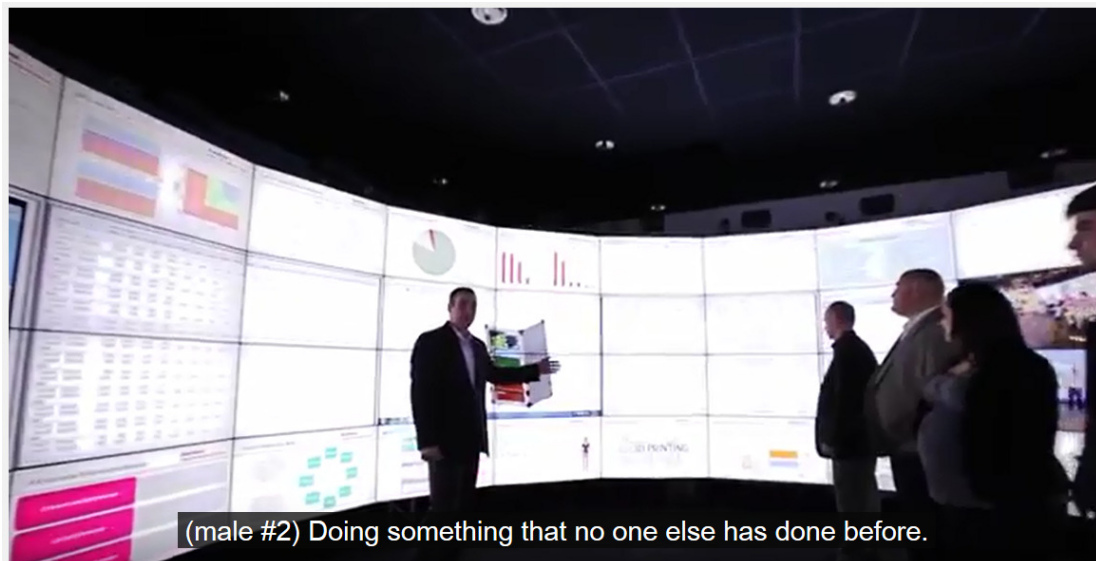
This presentation will address the questions of why do DFMA on new product development and how does lean fit in with DFMA. How DFMA measurably reduced or avoided costs or provided other benefits. The presentation will include case studies and open discussion with attendees on their reasons for doing DFMA and the results. A simple cost analysis will show the relationship between DFA and DFM and Lean and the cost savings opportunity. For those just considering or starting their DFMA journey, this presentation should serve to help develop the business case and expectations in their company for DFMA with lean.

Abstract approved by eTPCR # 14815

Presentation approved by eTPCR # 15214

Introduction

Raytheon Company Overview



(male #2) Doing something that no one else has done before.

<https://www.youtube.com/watch?v=8Dm41TFOLJk>

Our new company video is about our people, our technology, our vision, and the values we hold dear at Raytheon. (2:42)

Making the World a Safer Place



<https://www.youtube.com/watch?v=8B-k34faFAE>

Across missions. Across domains. Across continents. Raytheon engineers are powering leading-edge technologies that help the U.S. military make the world a safer place. (1:08)

Raytheon Introduction - YouTube

Notes & Credits

- Boothroyd Dewhurst, Inc.
 - Host of the 33rd Annual International DFMA forum
- Contributors:
 - Raytheon enterprise operations and mechanical councils and DFMA team members
 - The success we have realized is a result of many Raytheon employees that embraced DFMA and brought its practice into Raytheon years back and the functional councils that sponsored a cross Raytheon DFMA initiative.
 - Raytheon leadership from our Mechanical Engineering Director and up to the CEO (past and present) that have supported R6s and DFMA.
 - Our suppliers. Our customers.

DFMA is **delivering affordable customer solutions** in an increasingly competitive global marketplace