



Raytheon

Prepared for:  BOOTHROYD DEWHURST, Inc.
32nd International Forum on Design for Manufacture and Assembly

Product Affordability through Enterprise DFMA Implementation with Increased Productivity and Effectiveness

Raytheon Integrated Defense Systems

June 6th and 7th 2017

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Presentation Outline

- Raytheon introduction
- Expansion and standardization of DFMA application across a large enterprise
- Methods to improve effectiveness and productivity include:
 - common tool sets
 - project infrastructure
 - cross functional collaboration
 - supplier engagements
 - electronic brainstorming
 - digital model and advanced visualization
 - incorporation of lean manufacturing initiatives
 - challenges overcome, include changing the corporate culture
 - and early product development engagement



Product affordability through enterprise DFMA Implementation with increased productivity and effectiveness

Introduction

Raytheon Company – A technology and innovation leader specializing in defense, civil government, and cyber security solutions throughout the world

2016 Net Sales: \$24 Billion
63,000 Employees Worldwide
Headquarters: Waltham, MA



Raytheon is a “Manufacturing” company



HISTORY

Since our founding in 1922, Raytheon has been at the forefront of new defense technologies and their conversion for use in commercial markets. 6/9/2017 | 3

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Introduction

Our Vision: One global team creating trusted, innovative solutions to make the world a safer place

GOALS

- **Global Growth:** Increase domestic and international business by focusing on electronic warfare; cyber; missile defense; command, control, communications, computers, cyber and intelligence; precision weapons and training solutions.
- **Enterprise Collaboration:** Build a one-Raytheon culture of disciplined collaboration for results.
- **Competitive Advantage:** Develop deep customer relationships, drive flawless performance, and deliver solutions that are more effective and affordable than those of our global competitors.

DFMA addresses the enterprise collaboration and competitive advantage goals



Introduction

OUR BUSINESSES ARE ORGANIZED BY KEY MISSION AREA



Cross organizational collaboration

Five businesses in the Company

Introduction



MISSILE DEFENSE



COMMAND AND CONTROL



SENSORS AND IMAGING



CYBER



ELECTRONIC WARFARE



PRECISION WEAPONS



TRAINING



MISSION SUPPORT

Raytheon provides state-of-the-art electronics, mission systems integration and other capabilities as well as a broad range of mission support services.

Introduction

Raytheon Company Overview



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

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

Introduction



Global collaboration is a necessity

Introduction



**Products & Services are...
High Mix
Low Volume
High Reliability, Robust,
Lives depend on them**



“DFMA” is...

- Wikipedia: **DFMA** stands for Design for Manufacture and Assembly. **DFMA** is the combination of two methodologies; Design for Manufacture, which means the design for ease of manufacture of the parts that will form a product, and Design for Assembly, which means the design of the product for ease of assembly.
- Tool, Process, Technique,...
- Activity such as workshop or design review method
- Culture
- A trade mark held by Boothroyd Dewhurst – DFMA®

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

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

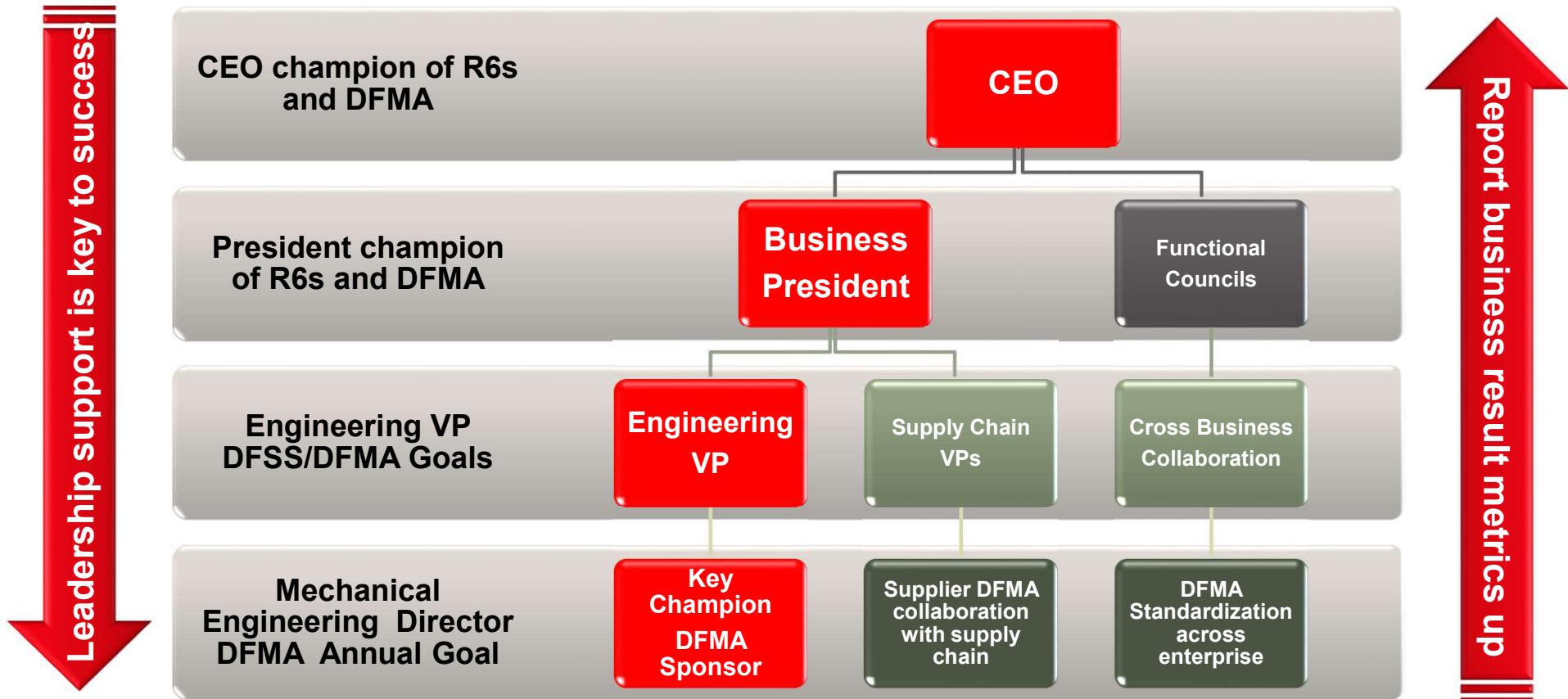
Expansion and Standardization of DFMA Application Across a Large Enterprise.



- Identified DFMA enterprise wide usage
- Initiated transition to build project
- Formed Enterprise DFMA Team
- Collected DFMA **templates, training, and process** from across business
- Collaborated with team to identify and **standardize** to one set of documents
- Prioritized corporate funded projects
- Set DFMA goals at VP level of engineering
- **Flowed down goals** to organizations
- Established **accountability** through HR process
- Established DFMA steering team cadence



Expansion and Standardization of DFMA Application Across a Large Enterprise.



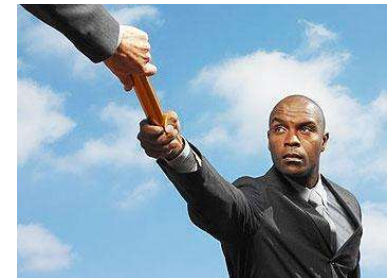
Allocate DFMA goals to department, section, and individual contributors

Enterprise DFMA Common Toolsets

- To improve productivity and flexibility with multiple leads:
 - Collaborated with team to identify and standardize to one set of documents
 - Developed standard work, standard tools, standard process
 - ❖ Check List
 - ❖ Pre-work shop templates
 - ❖ Workshop templates
 - ❖ Out brief templates
 - ❖ Templates for introduction
 - ❖ Standard Invitations & communications
- All available and linked in web based accessible location
- All workshop metrics are available, except proprietary data
- Easy to hand off from one lead to another if conflicts arise

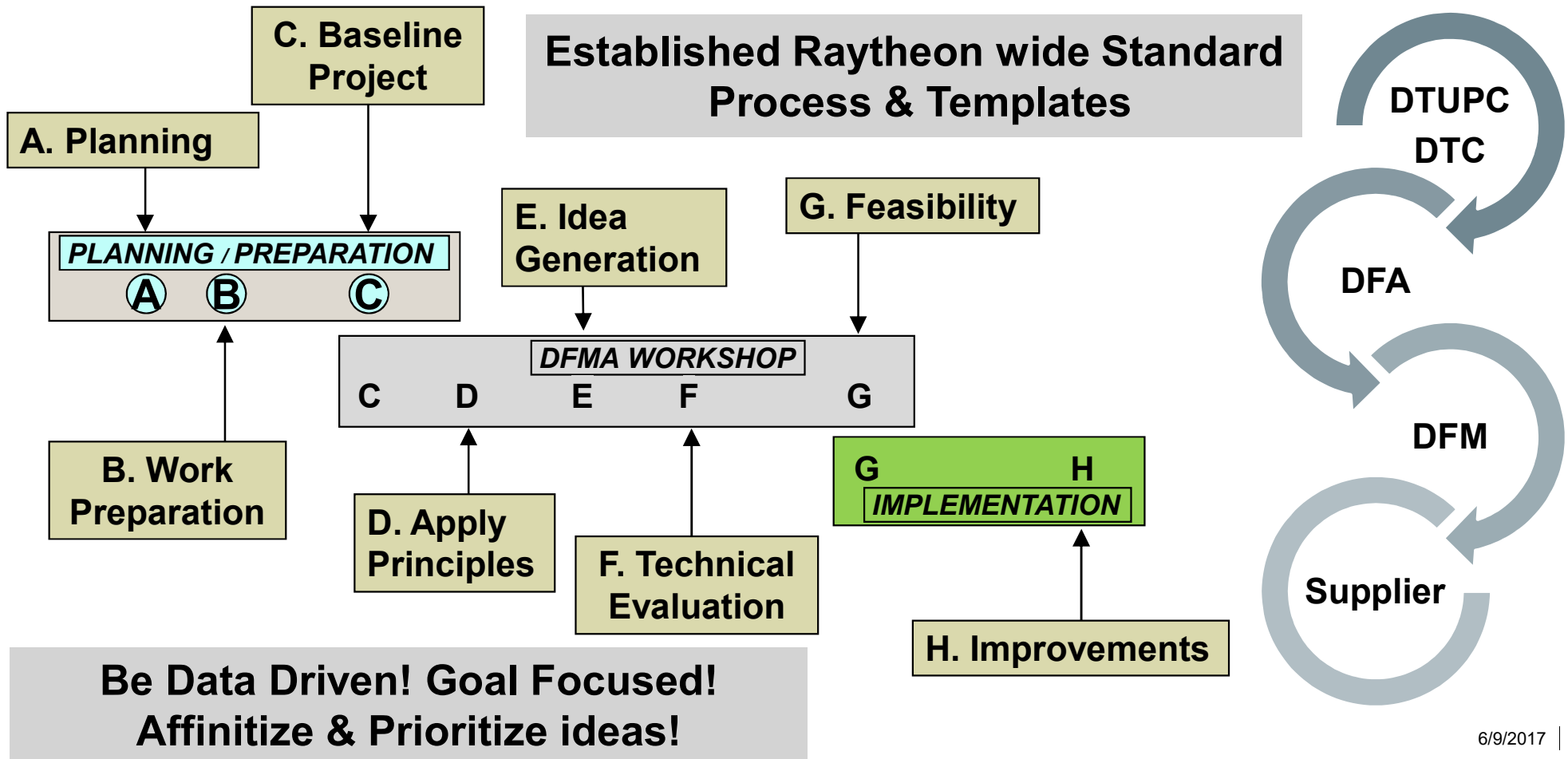


Electronic Training



Standard Work, Process, Tools, Templates in Common Data Base and Store Completed Artifacts and Manage Metrics

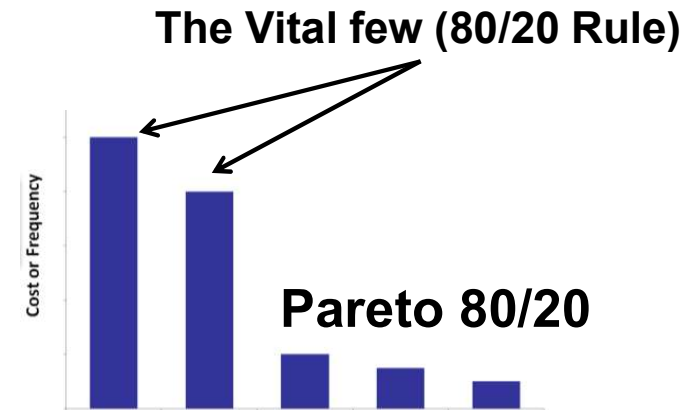
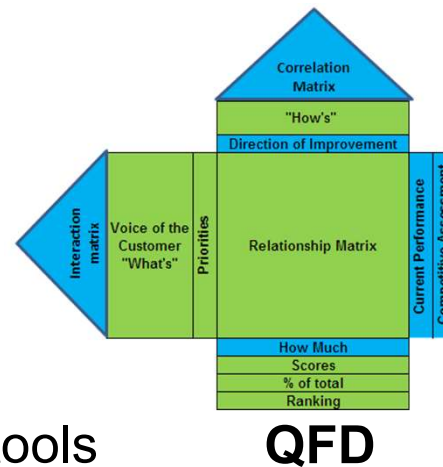
Enterprise DFMA Common Toolsets



Enterprise DFMA Common Toolsets

Standard Process & Tools

- Cost Modeling & Analysis
- Quality Function Deployment
- Risk Assessment Tools
- Ease Impact Charts
- FMEA, PFMEA, Producibility tools
- Value Stream Mapping
- Reverse Planning
- Lean Methods
- Additive Manufacturing
- Immersive Technology



Brainstorming
*All ideas are good
 Some have higher ROI*

Ease-Impact

High	Plan	Seriously Consider
Low	Drop	Consider
	Hard	Ease Easy

Infrastructure: Tracking Database

- SharePoint database with 6 step workflow process
- Document repository of project asset management

Technical Element Supplier Involvement ? St

- ▣ Status : 1 - Engaged (56)
- ▣ Status : 2 - Funded (3)
- ▣ Status : 3 - Workshop (11)
- ▣ Status : 4 - Out Briefed (6)
- ▣ Status : 5 - Program Approved Projects (2)
- ▣ Status : 6 - Completed (429)

DFSS Activities - DFMA Tower

Edit

Save Close Paste Copy Cut

Commit Clipboard

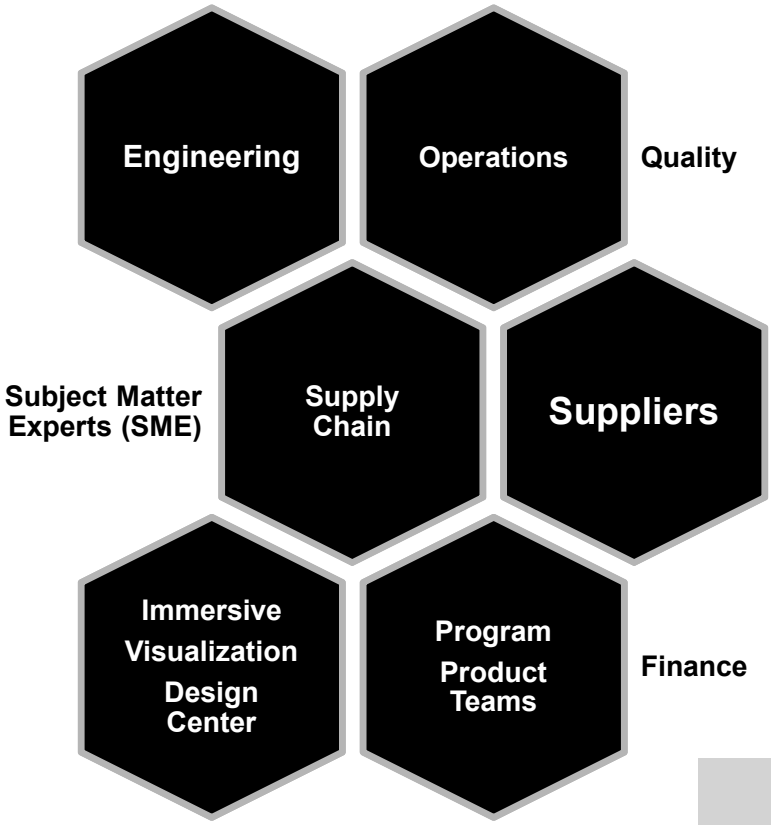
Notional Example

ID	1,2307
Cancel ?:	—
Technical Element	Choose from the following or enter your own value. Design for Mfg and Assy w/ Sustainment
Event Type	Deployment
Supplier	Supplier A
Title	DFMA Tower
Program	Choose from the following or enter your own value. Space Tower
Assembly	Tower
CAVE Event	—
POC	Choose from the following or enter your own value. Mark Steudel
Department	Manufacturing Engineering
Sponsor	Choose from the following or enter your own value. Mark Steudel



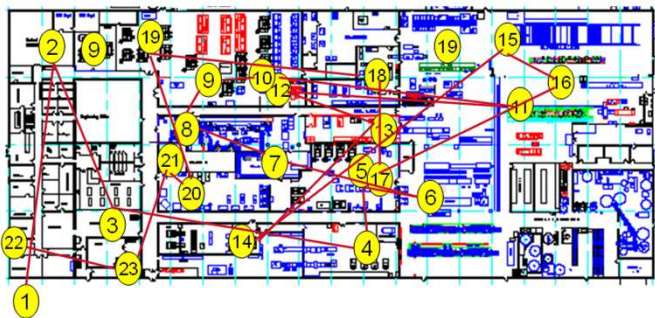
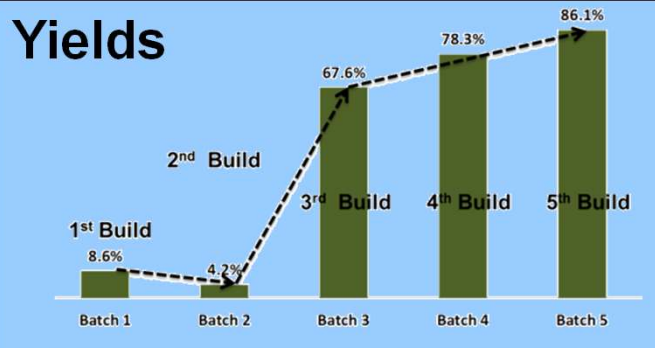
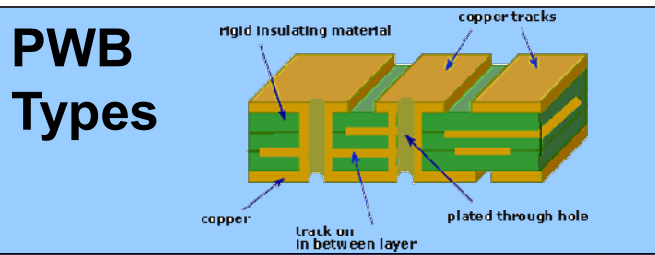
Cross functional collaboration

DFMA leads and team members learning through cross discipline and cross Raytheon DFMA projects



DFMA is a team sport: requires multi-discipline contribution

Supplier Engagements



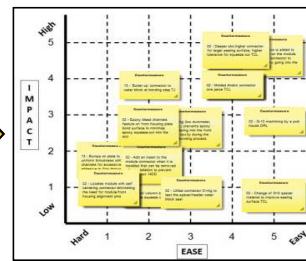
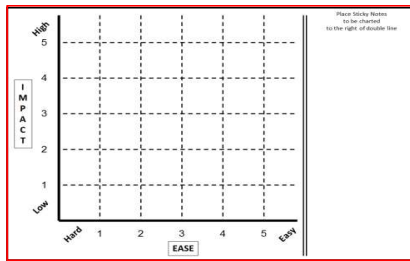
Design for Manufacturing and Assembly

- **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
- **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

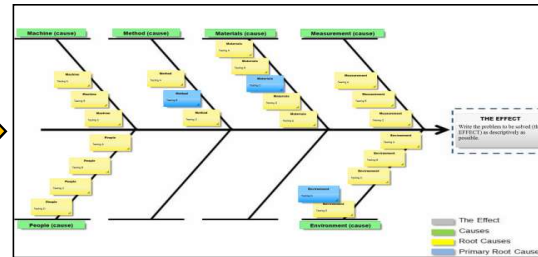
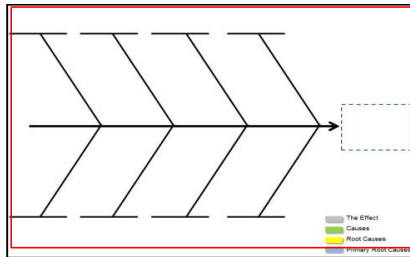
Electronic Brainstorming

Ease Impact Chart



Original Order	Description	Ease of Implementation	Impact expected on the job to be done (Weight, Cost)	Score Higher is better
26	If adhesive is added to the connector on the module, put a Kapton connector to minimize epoxy going into the contacts HDD	5	5	25
14	Hole geometry change to manage squeeze out DRL	4	5	20
22	Increase cross section of slot to allow for easier more complete backfill TCM	4	5	20
24	Seal and backfill at same time to preclude second sealing step DRL	4	5	20
31	Deeper slot, higher connector for larger sealing surface, higher tolerance for squeeze out TCL	4	5	20
15	Reduce quantity of adhesives DRL	4	4	16
27	Change to seal DRL	4	4	16

Fishbone Diagram



Brainstorm Name	Effect	Title	Description
1	Fishbone	Write the problem to be solved (the EFFECT) as descriptively as possible.	
2	Fishbone	People (cause)(R)	Testing A
3	Fishbone	People	Testing B
4	Fishbone	People	Testing C
5	Fishbone	People	Testing D
6	Fishbone	Method (cause)(R)	Testing A
7	Fishbone	Method	Testing B
8	Fishbone	Method	Testing C
9	Fishbone	Measurement (cause)(R)	Testing A
10	Fishbone	Measurement	Testing B
11	Fishbone	Measurement	Testing C
12	Fishbone	Measurement	Testing C
13	Fishbone	Materials (cause)(R)	Testing A
14	Fishbone	Materials	Testing B
15	Fishbone	Materials	Testing C
16	Fishbone	Materials	Testing A
17	Fishbone	Materials	Testing B
18	Fishbone	Materials	Testing D
19	Fishbone	Materials	Testing A
20	Fishbone	Machine (cause)(R)	Testing A
21	Fishbone	Machine	Testing B
22	Fishbone	Machine	Testing C
23	Fishbone	Machine	Testing A
24	Fishbone	Environment (cause)(R)	Testing B
25	Fishbone	Environment	Testing A
26	Fishbone	Environment	Testing D
27	Fishbone	Environment	Testing C
28	Fishbone	Environment	Testing C

Blank Background (Action Items)



Action ID	Reference	Action Title	Owner	Start Date	Start Assigned	Plan Use	Output Date	Actual Date	Comments	Resolution
1		Verify and confirm that the number of items selected for testing is correct and that the test plan is complete.	Yes							
2		Verify that the test plan is complete and that the test plan is correct.	Yes							
3		Verify that the test plan is complete and that the test plan is correct.	Yes							
4		Verify that the test plan is complete and that the test plan is correct.	Yes							
5		Verify that the test plan is complete and that the test plan is correct.	Yes							
6		Verify that the test plan is complete and that the test plan is correct.	Yes							
7		Verify that the test plan is complete and that the test plan is correct.	Yes							
8		Verify that the test plan is complete and that the test plan is correct.	Yes							
9		Verify that the test plan is complete and that the test plan is correct.	Yes							
10		Verify that the test plan is complete and that the test plan is correct.	Yes							
11		Verify that the test plan is complete and that the test plan is correct.	Yes							
12		Verify that the test plan is complete and that the test plan is correct.	Yes							
13		Verify that the test plan is complete and that the test plan is correct.	Yes							
14		Verify that the test plan is complete and that the test plan is correct.	Yes							
15		Verify that the test plan is complete and that the test plan is correct.	Yes							
16		Verify that the test plan is complete and that the test plan is correct.	Yes							
17		Verify that the test plan is complete and that the test plan is correct.	Yes							
18		Verify that the test plan is complete and that the test plan is correct.	Yes							
19		Verify that the test plan is complete and that the test plan is correct.	Yes							
20		Verify that the test plan is complete and that the test plan is correct.	Yes							
21		Verify that the test plan is complete and that the test plan is correct.	Yes							
22		Verify that the test plan is complete and that the test plan is correct.	Yes							

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Digital Model and Advanced Visualization



Benefits of model based digital DFMA

- Earlier – before drawings created
- Higher ROI – earlier is better
- Improved communication
- Able to “See” and simulate better

SAFETY FROM EVERY ANGLE

RAYTHEON EMPLOYEES ARE TRAINED TO CREATE A SAFER ENVIRONMENT.



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**

Design for “X” adaptation of DFMA methods

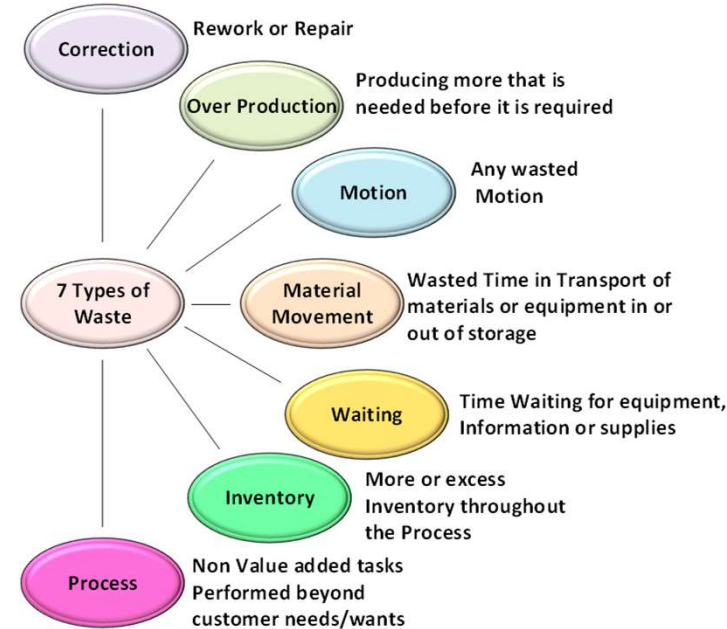
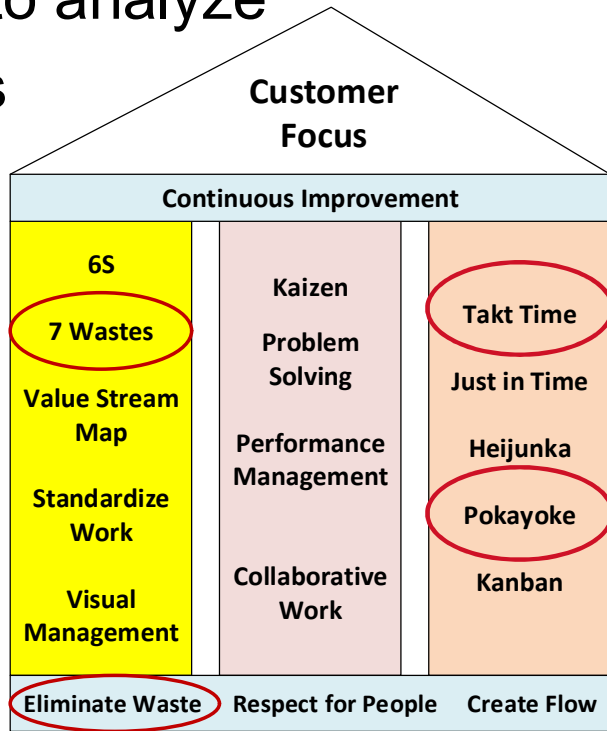
- Assembly
- Manufacture
- Test
- Safety
- Quality
- Virtual simulation and risk reduction
- Cycle time for on time delivery
- Sustainment (Ownership cost)
- Additive manufacturing (DFAM)
- Specialty engineering



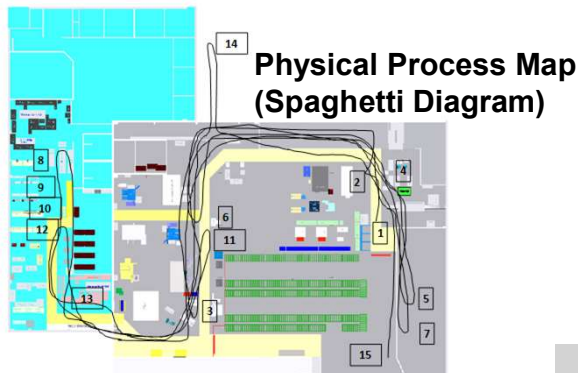
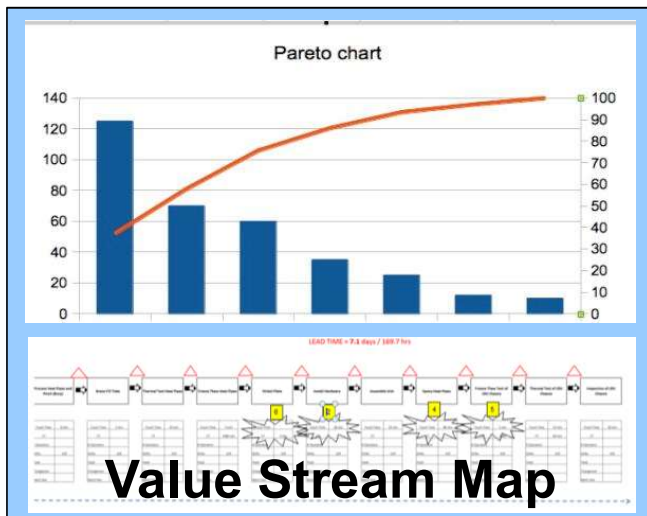
Incorporation of Lean Manufacturing Initiatives.

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

Design & Manufacturing process optimization



Supplier Engagements with Lean



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

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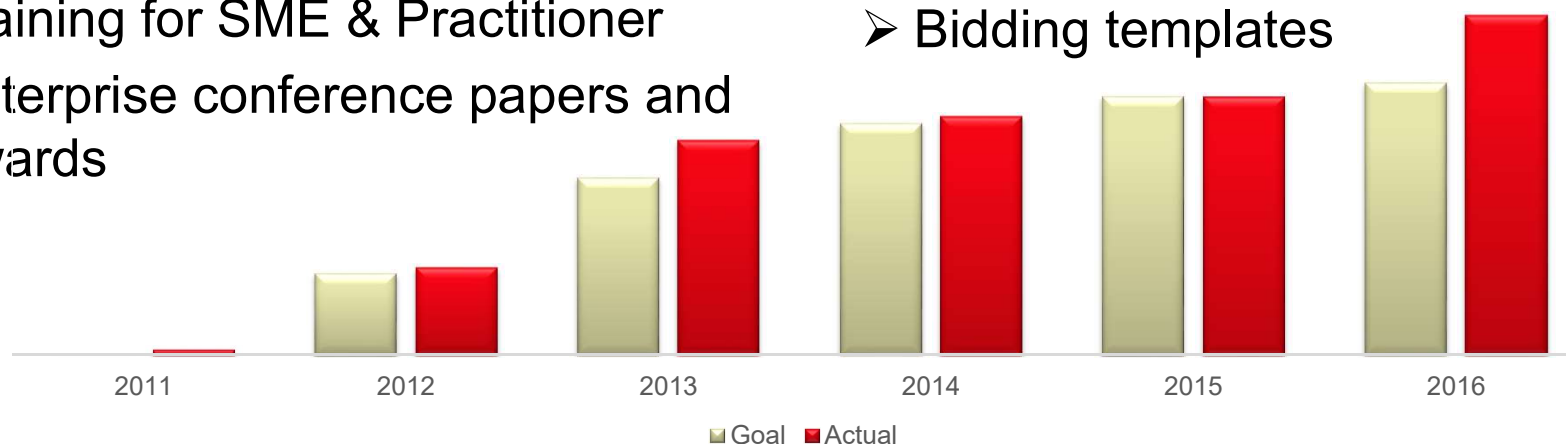
Overcoming Challenges

Changing the corporate culture

- 5 Years of identifying / working opportunities
- Champion: CEO and division VPs
- Goals set at VP level
- Goal Flow down
- Training for SME & Practitioner
- Enterprise conference papers and awards

Early product development engagement

- IRADS
- CRAD
- Identifying opportunities
- Early process gates
- Bidding templates

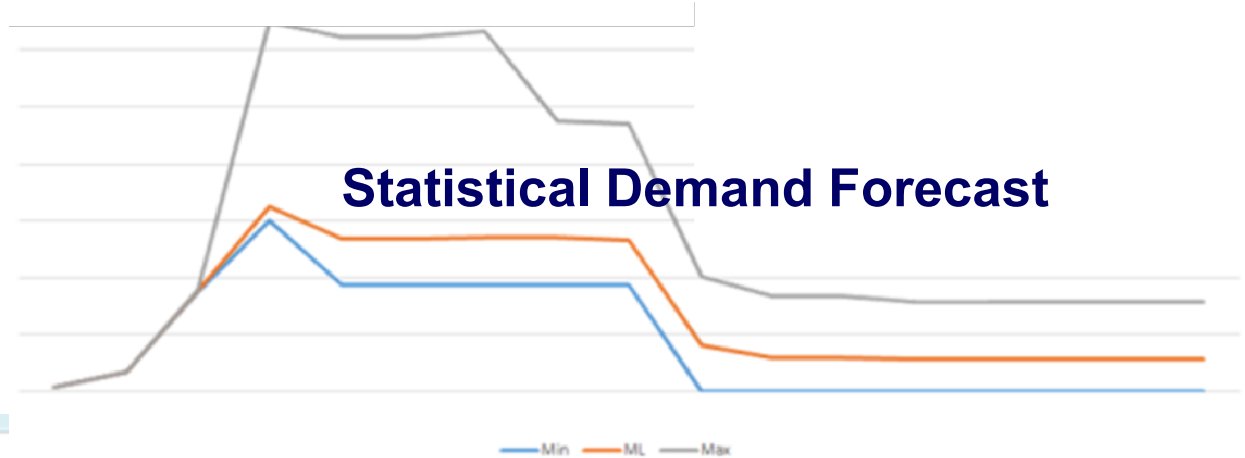
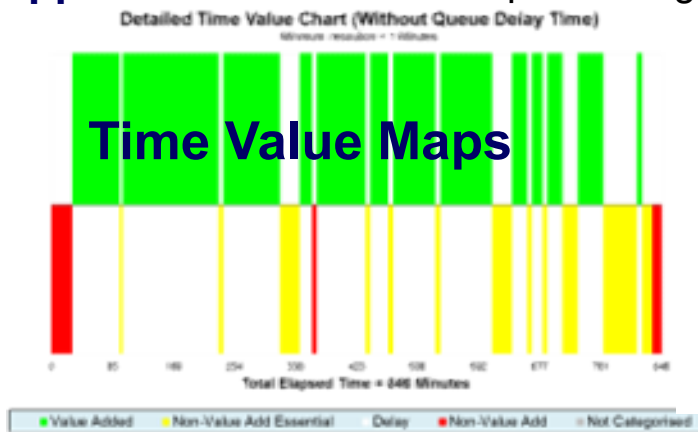


Case studies in DFMA implementation

Path Identified to Affordable product, Expanded Addressable Market

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**

Achieve

- **DFMA proliferating across enterprise enabling global growth through affordability to position Raytheon with competitive advantage**
 - Delivered **100's of enterprise wide DFMA** including supplier engagements, resulting in over a 100's million dollars in business benefit over 3 years
- **Process**
 - DFMA leading the **adoption & evolution of virtual reality**
 - **Early product development focus** for multiple program impact and early influence
 - Raytheon Invention Award for collaboration software
 - **Experiential DFMA learning** for 1000's of Raytheon and supplier employees
- **Culture**
 - **Institutionalized DFMA as THE go-to methodology across the enterprise** delivering affordable customer solutions in an increasingly competitive marketplace

So What?

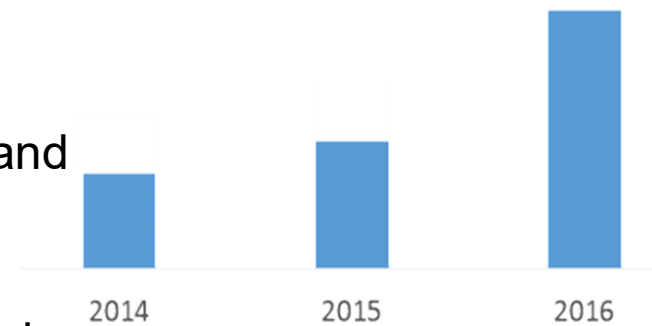
Raytheon:

- Raytheon Program Manager:
“Best implementation of DFMA I have seen in my 35 years.”
- Program Performance: Improvements in CT, Quality, & Yield
- People Impact: Developed DFMA Leads, including DFSS Affordability R6σ Principle Specialists (Green belts), to sustain and grow in what we have done and what we will do in the future

Customer:

- Raytheon DFMA recognized as a **best practice** by our Navy and Air Force customers
- CMMI Level 5 Assessor recognized DFMA as one of five best practices with world-class expertise to support these activities
- Due to the High CMMI Maturity of DFMA the DFSS Team received 2016 IEEE Computer Society/SEI Watts S. Humphrey Process Achievement Award

100's of Enterprise DFMA Deployments



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

Internal Recognition

2013 RAYTHEON
SIX SIGMA
awards

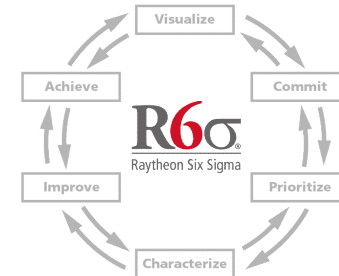
Raytheon

DFMA project recognized for 2013 results at Enterprise level with the CEO and leadership team.



Raytheon Six Sigma™ is our disciplined, knowledge-based approach designed to increase productivity, grow the business, enhance customer satisfaction and build a customer culture that embraces all of these goals.

- Specify value in the eyes of the customer
- Identify the Value Stream: eliminate waste and variation
- Make value flow at the pull of the customer
- Involve, align, and empower employees
- Continuously improve knowledge in the pursuit of perfection



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Questions



Raytheon

Raytheon

Notes & Credits

- Boothroyd Dewhurst, Inc.
 - Host of the 32nd 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.
 - Raytheon eTPCR IDS-11158

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

Who we are



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 the JLENS 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



Brian Foley

- Raytheon Company IDS DFSS/DFMA Lead
- Brian Foley is an Engineering Fellow within Design For Six Sigma part of IDS Engineering Strategic Development. During his 33 years at Raytheon, Brian has held positions of increasing responsibility within Design Engineering. Brian is a certified R6s Expert Leading Design for Manufacturing and Assembly, Design for Six Sigma with Suppliers, Lean, and Innovation. In 2010 Brian and his Ceradyne team received The R6r CEO and Presidents Award. Brian is a USAF Veteran and holds a BS in Electrical Engineering from University of Lowell, a MS in Microwave Electrical Engineering from UMass Amherst.



Dan Bardsley

- Raytheon Company IDS DFSS/DFMA Lead
- Dan Bardsley has been working for Raytheon for 13 years. He is currently working in the Design For Six Sigma (DFSS) team under the Strategic Development department. He has hands-on experience in the DFSS technical focus areas of: Design For Manufacturing and Assembly (DFMA), Critical Chain Project Management with reverse planning, and Critical Parameter Management. His experience at Raytheon includes five years on the IDS Engineering Process Group as Assets Manager across all process disciplines and as a CMMI- SCAMPI Class A - Level 5 appraiser. Other experiences include: Deputy Configuration / Data Manager within Zumwalt Program Management Office. He has a Mechanical Engineering and a Materials Management background servicing DoD, Dot, and commercial based companies.

eTPCR # 10888 Abstract

Case studies in DFMA implementation will be shared including the expansion and standardization of DFMA application across a large enterprise. Methods to improve effectiveness and productivity include common tool sets, project infrastructure, cross functional collaboration, supplier engagements, electronic brain storming, digital model and advanced visualization, and incorporation of lean manufacturing initiatives. Challenges overcome include changing the corporate culture and early product development engagement.